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Number to Sound

The Musical Way to the Scientific Revolution

Edited by

Paolo Gozza

NUMBER TO SOUND

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The Musical Way to the Scientific Revolution

Edited by

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Daniel P. Walker (30 June 1914 - 10 March 1985) published two collections of essays on music: *Studies in Musical Science in the Late Renaissance* (1978), and *Music, Spirit and Language in the Renaissance* (1985) edited by Penelope Gouk. His “Musical Humanism in the 16th and early 17th Centuries” (*The Music Review*, 1941-42) is a landmark in the field of Renaissance musical theory.

Preface

Number to Sound: The Musical Way to the Scientific Revolution is a collection of twelve essays by writers from the fields of musicology and the history of science. The essays show the idea of music held by European intellectuals who lived from the second half of the 15th century to the early 17th: physicians (e.g. Marsilio Ficino), scholars of musical theory (e.g. Gioseffo Zarlino, Vincenzo Galilei), natural philosophers (e.g. Francis Bacon, Isaac Beeckman, Marin Mersenne), astronomers and mathematicians (e.g. Johannes Kepler, Galileo Galilei). Together with other people of the time, whom the Reader will meet in the course of the book, these intellectuals share an idea of music that is far removed from the way it is commonly conceived nowadays: it is the idea of music as a science whose object—musical sound—can be quantified and demonstrated, or enquired into experimentally with the methods and instruments of modern scientific enquiry. In this conception, music to be heard is a complex, variable structure based on few simple elements—e.g. musical intervals—, combined according to rules and criteria which vary along with the different ages. However, the varieties of music created by men would not exist if they were not based on certain musical models—e.g. the consonances—, which exist in the mind of God or are hidden in the womb of Nature, which man discovers and demonstrates, and finally translates into the language of sounds.

The discourses on music of the 16th and early 17th century European intellectuals bear witness to the change in their shared conception of music. The title of the book paraphrases this change: it is the shift from a conception in which the object of music, i.e. sound, is thought of in terms of number to the conception in which sound is thought of in terms of movement. “Number does not produce sound,” Marin Mersenne states; it has no separate, autonomous reality from the periodical oscillations of those sounding bodies that in some mysterious way engender the sensation of sound in man. In short, it is the transition from the ‘sonorous number’ to

the ‘sonorous body,’ from *number* to *sound*. This is a subtle but substantial change in the nature of ‘music as a science,’ which integrates and transforms the musical tradition of ancient and medieval origin.

The structure of the book makes the epistemological phases in this change clear. The metamorphosis from number (*Tradition*) to sound (*Reassessment*) is complicated by a phase of gestation (*Transition*), the cognition of which gave rise to the planned symmetries of the text. The outcome is a tripartite structure (the three main sections of the book.) Each section is twofold: ontological—the object of music (sound) in terms of number (*Tradition*: section 1), measure (*Transition*: section 3) and matter and motion (*Reassessment*: section 5)—, and psychological—music as a case of the mind-body relationship in Renaissance and late-Renaissance Magic (*Tradition*: section 2) and in the Age of Mechanicism (*Reassessment*: section 6), tempered by an experimental attitude (*Transition*: section 4). Every heading introduces two narrative voices: those of the Authors, past and present, who take turns in telling the story. The Editor apologizes for having made use of them in this experiment. His main concern here has been to compensate for this instrumental use with the clarity of the premise and the proper design of the book. Finally, the Introduction offers the Reader the coordinates of a tradition that from ancient times reaches its fulfilment in the 18th century. In order to cover such a vast period of time, each section of the Introduction is concerned with a self-sufficient theme—each paragraph may be read on its own—, and it repeats the same time-spans: from the Renaissance to the Age of the Enlightenment, when music moves house, it abandons the Department of Exact Science and enters the Department of Fine Arts.

‘The musical way to the scientific revolution’—the subtitle of the book—states an historical phenomenon that has not been awarded attention on the part of historians: in the 16th and 17th centuries music is a model for many intellectuals in their reconsideration of the structure of knowledge and reality. The crisis of number leads to the reappraisal of music in relationship to other, emergent disciplines—first geometry and astronomy, then mechanics and psychophysiology—, and the mobility of music in the encyclopedia of the sciences is a clue to its epistemological changes. In virtually the same years, music leads Descartes to *mathématique universelle* and method, Kepler to reformed astronomy, Mersenne to mechanics and Galileo to the science of motion, to mention the most obvious cases. Music contaminates culture, it modifies knowledge and is in its turn modified by it. The contribution of *Number to Sound* to ‘the musical way to the scientific revolution’ makes two points: first, the transition from *number* to sound (*weight*) is historically tempered by *measure*, and, second, the new conception of sound changed the way of considering man as the enjoyer of music—two inescapable points in a tradition that alongside

David and Orpheus, the archetypal music-physicians of the soul, places ‘God, the geometer and musician,’ who *cuncta in numero, pondere et mensura disposuit* (who arranged the whole by number, weight and measure.)

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I should like here to thank those people who have helped me in my work. Prof. H. Floris Cohen was very generous with suggestions and advice on all the—only too frequent—occasions I pressed him, which was the same fate of Dr. Penelope Gouk, who was equally helpful. I am very grateful to Prof. Claude Palisca for his uncommon availability and extraordinary professionalism. My thanks go to all the Authors, in particular the late Prof. Daniel P. Walker, whose study on the second or third floor of the Warburg Institute in London I had the chance to frequent at times way back in 1984. I also thank Dr. Carmel Ace, Dr. Steve Jewkes and Dr. Pascal Ernst (University of Bielefeld) for their work on the translation. Finally, I thank the Warburg Institute and E. J. Brill, Edizioni dell’Ateneo, Francke Verlag and Cornell University Press for their permission to reprint the articles by D. P. Walker, P. Gouk, M. Dickreiter and P. Dear.

This book was conceived in a difficult time at home, which prolonged its period of gestation, but is born in circumstances that look promising. I, therefore, dedicate it to little Vincent Boccadoro, whose birth on April 6th, 1998, at 9.15 a.m., is a token of good luck to all those who collaborated in the birth of the book and to those who will read it.

P.G.

INTRODUCTION

Paolo Gozza

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Demonstrating music

1 *Musical models*

Today musical theory is mainly “the study of the structure of music.”¹ Originally it was a mathematical discipline: its characters were not sounds but numbers, and the ratios between the numbers defined the relationships between the sounds. The problem of choosing the sounds to make music with, therefore, was the problem of selecting the right numbers to generate pleasant musical sequences, the consonances. This particular approach to the problem dates back to Pythagoras and the Pythagoreans (7-5th centuries B.C.). Within the framework of the cosmology of the Ionian philosophers, Pythagoras and the Pythagoreans set a universe of precision, quantitative and dualistic, against the approximative universe, qualitative and materi-

¹ Claude V. Palisca, entry “Theory, theorists,” *The New Grove Dictionary of Music and Musicians*, 20 vols. (London: Macmillan, 1980), 18:741-762, p. 741.

alistic, of the early naturalists. They were looking for a formal principle of the cosmos (number), not material (water, air, fire), and mathematical models rather than qualities became the basic constituents of reality. In Aristotle's words:

The so-called Pythagoreans applied themselves to mathematics, and were the first to develop this science; and through studying it they came to believe that its principles are the principles of everything. And since *numbers* are by nature first among these principles, and they fancied that they could detect in numbers, to a greater extent than in fire and earth and water, many analogues of what is and comes into being... and since they saw further that the properties and ratios of the musical scales are based on numbers, and since it seemed clear that all other things have their whole nature modelled upon numbers, and that numbers are the ultimate things in the whole physical universe, they assumed the elements of numbers to be the elements of everything, and the whole universe to be a proportion or number.²

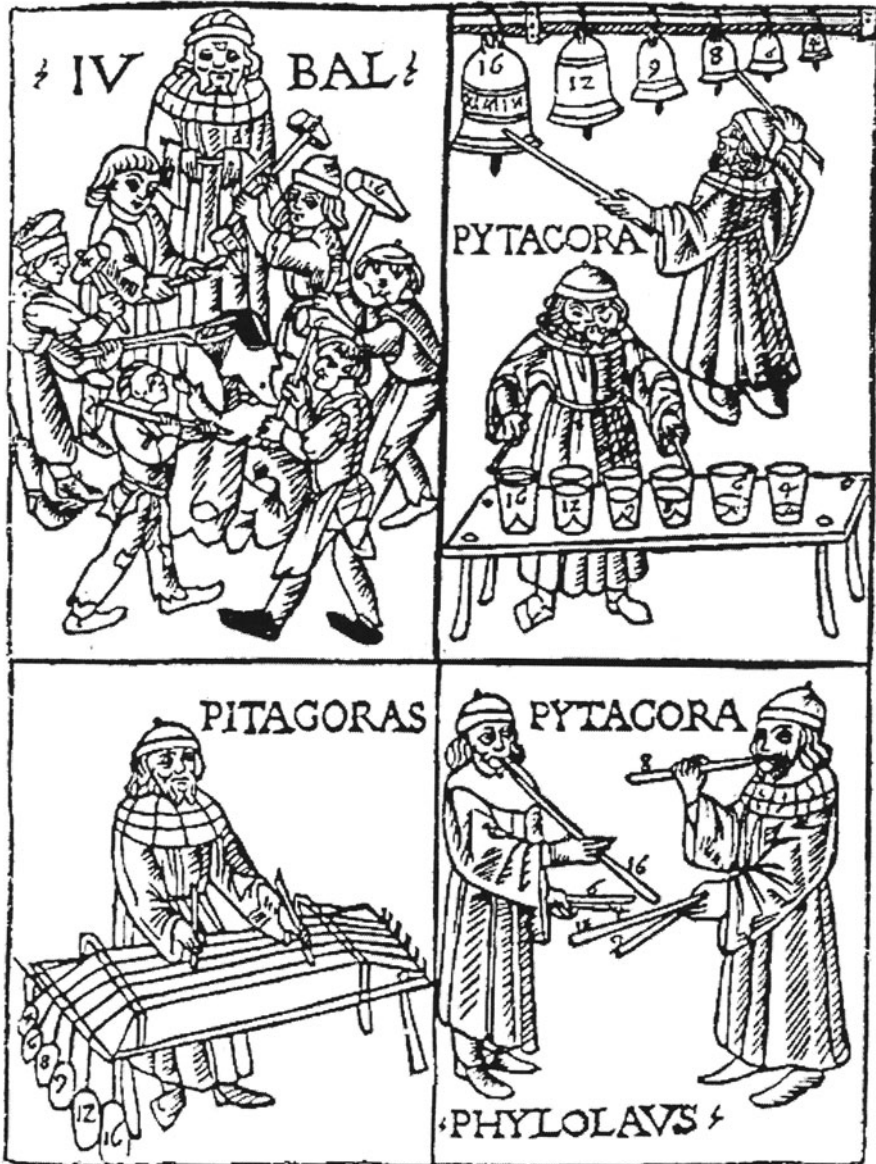
According to Aristotle, numbers are, in Pythagorean cosmology, the constituent principles and elements of the whole, and the whole is held together (cosmos) by mathematical proportion, the equivalent of musical harmony. Nothing is further from the constructionism of the first musical thinkers than the idea, common today, of the conventional nature of mathematical and musical objects.³ To the Pythagoreans musical and mathematical objects are the ultimate components of reality that the Greeks called *physis* (nature). The discovery of musical universals in nature is what Pythagoras is traditionally famous for.

Pythagoras, says Boethius, spent a day "for a divine chance" ("divino quodam casu") outside a work-shop. Inside, he noticed that four of the five hammers struck by the blacksmiths produced on the anvil a pleasant harmony. He weighed them: one hammer was respectively double ($^2/1$), one and a half ($^3/2$) and one and a third times ($^4/3$) heavier than the other three hammers it so pleasantly played along with. The fifth hammer, on the other hand, was dissonant. Pythagoras later perfected the experiment, first with strings, vases, water-filled glasses and pipes, (Figure 1) and finally with a certain and secure method he called canon or rule: a single string stretched over a sounding board to which a movable bridge is attached, so dividing the string into two parts in different ratios, known by the name monochord and still in use today for the investigation of musical ratios.⁴

² Aristotle, *The Metaphysics* 985b 24 - 986a 4, trans. Hugh Tredennick, 2 vols. (London: Heinemann, and Cambridge, Mass.: Harvard University Press, 1961), 1:33.

³ Simeon K. Heninger, Jr., *Touches of Sweet Harmony. Pythagorean Cosmology and Renaissance Poetics* (San Marino, California: The Huntington Library, 1974), pp. 75-76. See, also, Section 6 of this Introduction.

⁴ Anicius Manlius Severinus Boethius, *De institutione musica*, I, 10.



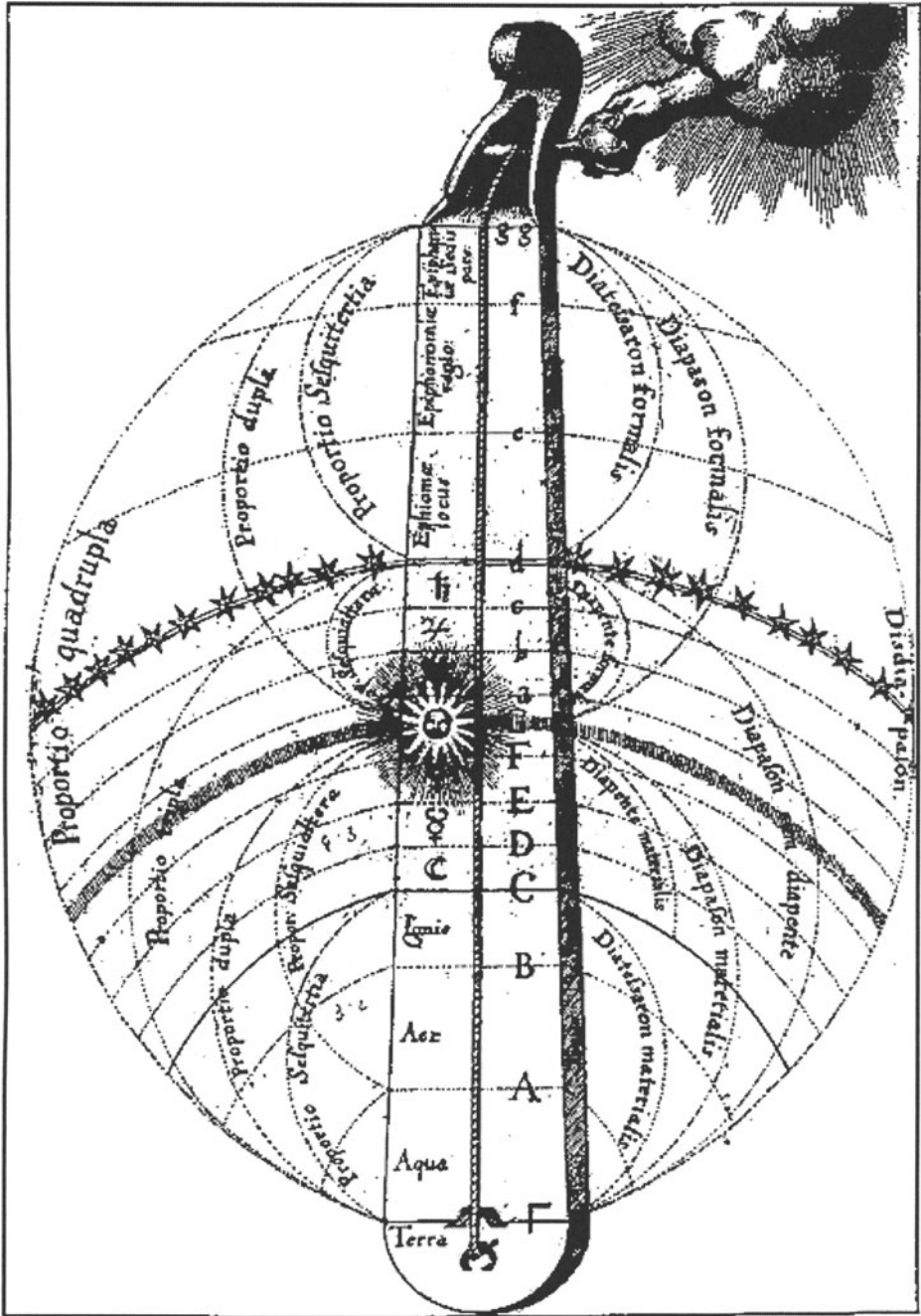
1. The invention of the consonances, from Franchino Gaffurio, *Theorica musice* (1492)

With the canon Pythagoras deduced three fundamental consonances: by dividing the string in two parts, one of which double ($\frac{2}{1}$), then one and a half ($\frac{3}{2}$) and finally one and a third ($\frac{4}{3}$) times longer than the other, and

plucking them, two notes of different pitch can be heard at a distance, respectively, of an octave (C-c), fifth (C-G) and fourth (C-F). In brief, the first most natural consonances are defined by the first four whole numbers, 1, 2, 3 and 4, the Pythagorean tetrad. With unison ($^1/1$, C-C), the Pythagorean consonances are thus expressed by two types of ratio: multiple, $^n/n$ —from which come two further consonances besides the octave: octave-plus-fifth ($^3/1$, C-g) and double-octave ($^4/1$, C-c₁)—, and superparticular, $^{n+1}/n$ —i.e. fifth ($^3/2$) and fourth ($^4/3$), the only consonances admitted by the Greeks within the octave. It follows that if an interval is consonant, then it is expressed by a multiple or superparticular ratio. The Pythagorean analogy between sound and number, between ratios among sounds and ratios among numbers, is therefore the principle of consonance—‘good ratios for good sounds’—and is also the principle that defines the order and classification of consonances—‘the best ratio for the best consonance’—, of which the octave takes arithmetical and musical primacy.⁵

The experiment of Pythagoras is the incipit of the mathematically oriented science of the Greeks. It shows how a mathematical order is immanent within physical space, and this order, both mental and perceptual, is the origin and foundation for harmony, musical or otherwise. The harmony expressed by the Pythagorean tetrad soon became the force that reconciles opposites and generates unity from diversity, many from one. Within this conceptual structure the monochord is both a scientific-didactic instrument and a scheme of the cosmos, the diagram that shows the mathematical and musical order of the universe. In the early 16th century Robert Fludd captures the classical and Christian conception of the harmony of the world with the image of the *monochordum mundi* (wordly monochord), on which the divine hand of the *Pulsator monochordi* (Player of the monochord) stamps His own rational order, mathematical and musical. (Figure 2) If Pythagorean musical theory is separated from the cosmology which informs it, it is not possible to comprehend its millenarian duration and it becomes difficult to understand why educated men, from Boethius to Newton, refused to challenge the authority of Pythagoras, even after a new musical language had pointed up the limitations and rigidities of the Pythagorean musical model.

⁵ Fabio Bellissima, *Epimoric Ratios and Music Theory*, to appear in the Acts of the 10th International Congress of Logic, Methodology and Philosophy of Science. Florence, August 1995.



2. The universe as a monochord, from Robert Fludd, *Utriusque cosmi... historia* (1617)

The limits of the Pythagorean model are the rigid distinction between consonance and dissonance defined by the first four numbers, and the search for the perfect system of intonation based on whole rational numbers. Let us go back to Gaffurio's plate depicting the discovery of consonances, (Figure 1) which in the minds of the men of letters remained up to the 18th century the archetype of musical science. In Gaffurio's table the numbers are not the first four simple integers but rather 6, 8, 9 and 12: they are the smallest numbers for producing the ratios of the consonances of octave, fifth and fourth, plus the distance between the fifth and the fourth, a tone, corresponding to the ratio $\frac{9}{8}$ ($\frac{3}{2} : \frac{4}{3} = \frac{9}{8}$). By means of the fundamental consonances it is possible to fix four notes (C-F-G-c) in the ambit of an octave (C-c), at intervals of a fourth, a tone and a fourth ($\frac{4}{3} \times \frac{9}{8} \times \frac{4}{3} = \frac{2}{1}$); therefore four notes are still needed to complete the octave, two inside each interval of fourth. The most immediate criterion consists in selecting the interval of tone $\frac{9}{8}$ between the two tetrachords (*i.e.* a four-note scale segment spanning a fourth). Since the difference between a fourth and two of such tones is $\frac{4}{3} : (\frac{9}{8})^2 = \frac{256}{243}$, the diatonic division of the tetrachord and consequently of the octave becomes:

$$C^{\frac{9}{8}} D^{\frac{9}{8}} E^{\frac{256}{243}} F^{\frac{9}{8}} G^{\frac{9}{8}} A^{\frac{9}{8}} B^{\frac{256}{243}} c$$

This scale is known as the Pythagorean or diatonic intonation.⁶ It was the most important among ancient Greek tunings, and in almost all the Medieval treatises it was the only one for which instructions to divide the monochord were given. As long as music was homophonic, based on octave, fifth and fourth, and sung, as in plainchant, Pythagorean intonation represented the theoretical framework for musical composition. From the 12th century these conditions were no longer general: music became polyphonic and the production of simultaneous intervals in song involved the use of intervals, major and minor thirds, not recognized in the Pythagorean scale where they are dissonant (major third C-E = $\frac{81}{64}$, and minor third A-c = $\frac{32}{27}$). The increase in consonances was accompanied in musical practice by the use of more complex musical rhythms. The introduction into 14th century polyphonic compositions of major and minor thirds, and the replacement of the ternary with the binary metre led to the break between modern musical praxis (*ars nova*) and academic musical theory which, apart from a few significant exceptions, generally reflected the *ars vetus*. Polyphonic music complicated the rigid Pythagorean borderline between consonance and dissonance, which was moved forward beyond the first

⁶ H. Floris Cohen, *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht/Boston/Lancaster: D. Reidel, 1984), pp. 34ff.

four whole numbers and beyond the consonance of fourth, to include the 'imperfect consonances' of third, major and minor.

The greater complexity of the consonance/dissonance relationship led to a questioning of the other premise of Pythagorean musical arithmetic: the search for the perfect system of intonation based on rational numbers. If consonance is thought to require simple number ratios, the arithmetic division of the octave cannot produce perfect intervals: ascending the scale seven octaves from a given C yields a C that is very close, but not identical, to the high C (really a B $\sharp$) reached by piling up twelve fifths: $(\frac{2}{1})^7 : (\frac{3}{2})^{12}$ is roughly $\frac{74}{73}$, a difference known as the 'Pythagorean comma', which makes itself heard as 'wolf-fifth', a pseudo-fifth exceeding the perfect $\frac{3}{2}$ by the comma. In other words, perfectly normal progressions, if made in perfectly pure intervals, result in clearly audible gains or losses in pitch.⁷ From the 15th century there was also the gradual emancipation of instrumental music, for organ and harpsichord, which eventually made the old system of intonation obsolete. As a result, there was a pressing need to establish a new system of intonation, capable of theoretically justifying musical compositions that could no longer be referred to the traditional Pythagorean and Boethian model.

The Renaissance discovery of the ancient Greek and Latin musical sources dramatized the problem of intonation. How is it possible to accommodate modern music with its theoretical principles in Greek and Latin culture, to which the Renaissance is heir? How can the polyphonic music of the Moderns be reconciled with the theoretical writings of Pythagoras, Boethius and the other ancient theorists, which had turned up in the libraries of the West from Byzantium?⁸ Unlike their medieval colleagues, the problem was acutely felt by Renaissance musical theorists precisely because of the rediscovery of a cultural heritage which besides the authority of Boethius and Pythagoras now ranked that of Aristoxenus and Euclid, Nicomachus and Ptolemy, Plutarch and Aristides Quintilianus, Porphyry, Alypius, and so on. An answer to the dilemma of Renaissance music came from the encounter between an ancient Greek codex recently translated into Latin and a modern reader who combined a Humanistic culture with a knowledge of musical theory and practice. The ancient Greek codex is Ptolemy's *Harmonics*,⁹ the modern reader is Gioseffo Zarlino. Among the various mathematical models of musical scale put forward

⁷ Ibid., p. 38.

⁸ See Section 4 in this Introduction.

⁹ Antonio Gogava, trans., *Aristoxeni Musici antiquiss. Harmonicorum Elementorum libri III. Cl. Ptolemaei Harmonicorum, seu de Musica lib III. Aristotelis de obiecto Auditus...* (Venice: Vincentius Valgrisius, 1562); see Claude V. Palisca, *Humanism in Italian Renaissance Musical Thought* (New Haven and London: Yale University Press, 1985), pp. 133-142.

by Ptolemy, Zarlino picked out the “diatonic syntonon” (the “right division of tone”) as the instrument for his theoretical reform.¹⁰ Ptolemy’s diatonic syntonon permitted Zarlino to resolve the dilemma of Renaissance music, both by reforming from within the Pythagorean-Boethian tradition and by adapting it to the musical praxis of the time. Through harmonic and arithmetic proportion it is possible to divide the octave into a fifth and a fourth, the fifth into a major and minor third and the major third into a major and minor tone, then experimentally prove the correctness of the mathematical procedure on the monochord. The mathematical deduction of the new consonant intervals thus affords a different distribution of the intervals within the octave, known today as the scale of ‘just intonation’:

$$C^{8/9} \ D^{9/10} \ E^{15/16} \ F^{8/9} \ G^{9/10} \ A^{8/9} \ B^{15/16} \ c$$

Zarlino’s just intonation apparently resolved the two limitations of the Pythagorean model. It shifted the consonant borderline, availing itself of thirds and sixths—dissonants in the Pythagorean diatonic scale—on which the modern polyphonic construct was built. Furthermore all the consonances of the scale were just, *i.e.* defined by ratios between simple whole numbers ranging from 1 to 6 (*senario*): besides octave, fifth and fourth, thirds too, major C-E = $5/4$ and minor A-c = $6/5$, and sixths, major C-A = $5/3$ and minor E-c = $8/5$.¹¹

Without radically changing tradition, Zarlino’s *senario* was the true ‘sounding number’, the archetype of the theory and practice of modern music. With arguments drawn from numerological speculation, the *senario* became the “simulacrum of the world,” the symbol of the tripartite harmony of Boethius, found both in *musica mundana* and *humana*, in the macrocosm and in the microcosm.¹² The perfection of the *senario* could moreover be argued using an idea of the Pythagoreans themselves. In their arithmology the category of absolutely perfect numbers is that of the numbers identical with the sum of their own factors, and $6=3+2+1$ is the first of these numbers. In his *Elements* Euclid argued the perfection of 6, showing that it is the result of the sum and of the product of the first three whole

¹⁰ Gioseffo Zarlino, *Sopplimenti musicali* (Venice: Francesco de’ Franceschi Sanese, 1588), p. 8: “The forms of the consonances and other intervals that we use in our times in vocal and natural compositions are not products of art nor inventions of man but primarily of nature itself... They are then ordered and rediscovered by art in the species that I call and shall always call natural, named sytonic diatonic by Ptolemy” (trans. Palisca, *Humanism*, p. 272). See, also, Section 6 of the present Introduction.

¹¹ The minor sixth $8/5$, not contained in the *senario*, is perceived by Zarlino as made up of the fourth $4/3$ and the minor third $6/5$, while the embarrassment of the presence of the number 8 is countered by the argument that the 8 is two times 4 and hence potentially, even if not actually, contained in the *senario*.

¹² Palisca, *Humanism*, pp. 178-181, 247-248.

numbers: $1+2+3=1\times2\times3$; and for Ficino 6 is doubly perfect because it has the perfect ratio 2:1 within itself in that 6 equals $4+2$, and $4:2$ is the double ratio of 2:1.¹³

In Zarlino's intonation all the consonances are 'just', *i.e.* given by the 'natural' series of harmonic sounds. The term 'natural' does not mean 'experimentally proven'. In Zarlino it is opposed to 'artificial' and hence a synonym of 'not created by man', the result of a natural poiesis ordered by the Mind of the Creator; whence the repeated attempts, from Mersenne to Sauveur, to demonstrate the existence in nature of the mathematical series of consonances of the Zarlinian scale.¹⁴ Furthermore, precisely because of its use of pure intervals, the scale of just intonation is intrinsically unstable: it has a diminished fifth, D-A, as well as a diminished third, D-F, both of which are false by a syntonic comma, and this in the simpler diatonic music, apart from chromatic notes which would increase the number of intervals a comma or a diesis away from the corresponding pure intervals. The compromise reached in the 17th century with the introduction of equal temperament solved the problem by bringing an end to the interdiction of irrational numbers in musical theory, to that date seen as "a solemn and mysterious aspect of mathematics."¹⁵ On the other hand the decision to posit all the consonances as pure implies that it is impossible to keep the original pitch unchanged and certain concessions to the pitch of notes become necessary. What singers do in practice is the object of the 10-year controversy between Zarlino and Vincenzo Galilei. In this controversy the problem of intonation is at the forefront, bringing with it other contradictions pertaining to Renaissance musical culture.¹⁶

2 *Music as structure*

In her *Inner Music* Jamie Kassler skillfully reconstructs the intellectual attraction and wealth of speculation in Boethius' *musica humana*.¹⁷ The harmony of body and mind and their relationship presents Kassler's reader with a new dimension of the English 'experimental philosophy' of the 17-18th centuries. For the first time natural philosophy of the mind shapes natural philosophy of the musical instrument, which Kassler's thinkers as-

¹³ Michael J.B. Allen, *Nuptial Arithmetic: Marsilio Ficino's Commentary on the Fatal Number in Book 8 of Plato's Republic* (Berkeley: University of California Press, 1994), p. 51.

¹⁴ See Walker's essay in Section 1 of this Collection.

¹⁵ *Ibid.*; see, also, Cohen, *Quantifying Music*, pp. 38-43.

¹⁶ See Section 6 in this Introduction.

¹⁷ Jamie C. Kassler, *Inner Music. Hobbes, Hooke and North on Internal Character* (London: Athlone, 1995).

sume as a metaphor of human mentation. Musical instruments lie silent, and man as a musical instrument plays another music, 'inner music' as a construct of the mind-body relationship, and of the relationship of the self with the external world and with the mental archetype that encompasses and complicates both. Boethius' *musica humana* is thus the core of a conceptual structure informed by cosmological (Stoic and Neoplatonic), musical (Pythagorean) and medical (Galenic) traditions that the modern philosophers, from Thomas Hobbes to Robert Hooke and Roger North, interpret in the light of recent scientific discoveries: Harvey's theory of blood circulation, Galileo's science of motion and modern musical science.¹⁸

The conceptual structure of *Inner Music* has its roots in the conceptual structure of an ancient tradition, the intellectual tradition of music. In this tradition, which Boethius (ca. 480-526) epitomizes and hands down, *musica humana* communicates with the cosmological level of *musica mundana* (harmony of the cosmos) and with the artistic level of *musica instrumentalis* (harmonics).¹⁹ Boethius, who speaks to the philosophers, aligns music and philosophy: his tripartition is the musical rendering of the Aristotelian tripartition of theoretical philosophy into metaphysics, mathematics and physics, based on the Platonic triadic Being, intelligible, mediate and sensible. *Musicus* is therefore the philosopher who from sensible harmonies can cast back to metaphysical harmonies via intermediate harmonies, while *musica* is the science which investigates the source and foundation of harmony, musical or not, understood as order and proportion between the parts of a whole. That the book of the universe is written in mathematical language, that its characters are numbers, proportions, geometrical figures, and so on, also means that it is written in musical characters, the archetypes of the divine creation of the cosmos. This is what shapes the science of musical characters of the world, the ideal or idealized history of music written by philosophers, above which run the specific histories of music, written by musicians.

The paralleling of music and philosophy lies at the root of the extraordinary fortunes of Boethian *Musikwissenschaft*. The Renaissance inherited from Boethius the conceptual structure of music as an encyclopedia, the image of a universe created according to mathematical-musical archetypes, but it complicated the Boethian model. In the fifth chapter of the First Part of his *Le Istitutioni harmoniche* (1558), Gioseffo Zarlino (1517-1590) questions "What music in universal is, and its division." The questioning goes on to the tenth chapter, where Zarlino asks "What music in particular is, and why it is called thus."

¹⁸ See my review of *Inner Music* in *Annals of Science* 53 (1996): 642-644.

¹⁹ Boethius, *De musica*, I, 10.

“Music in universal,” Zarlino writes, “is no other than Harmony..., that quarrel and friendship Empedocles posited, from which he saw everything had perforce to be generated.”²⁰ Zarlino mentions here the mixture theory in Empedocles’ poem *On Nature*: the opposite universal forces of Love and Strife continually combine and separate the four substances—earth, air, fire and water—which is why each actual mixture is a balance and harmony of two separate cosmogonic forces.²¹ The mediation between cosmogony and musical theory in Empedocles is, as in Zarlino, number and proportion: proportion between the four elements of the cosmos (cosmogony) and proportion between the four tones that represent the Greek tetrachord (harmonics).

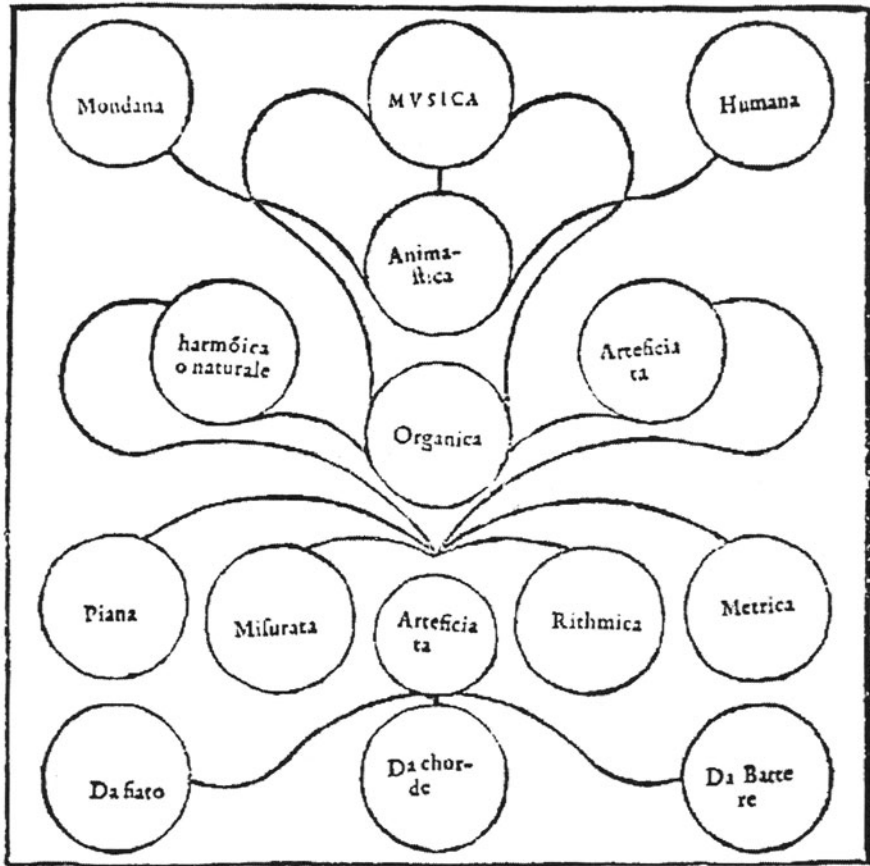
“Music in universal” is then divided by Zarlino into two parts: “animastic” and “organic.” “Animastic” is a term that refers to the world-soul in Plato’s *Timaeus*, and includes the *musica mundana* and *musica humana* of Boethius: harmony of the macrocosm and harmony of the microcosm, musical cosmology and musical anthropology. The “organics”—from “organo” that refers both to the organs of the human body that produce the voice and to the musical instruments made by man—is Boethius’ *musica instrumentalis*. Integral parts of “organic” music are “harmonics, or natural music” and “artificial music:” they are the harmony of natural instruments (Nature) and the harmony of artificial instruments (Art), the former divided into “plain,” “measured,” “rythmical” and “metrical” music (applicable also to artificial music), the latter divided according to the nature of the musical instruments: “wind,” “string” and “percussion”.²² (Figure 3)

Zarlino refashions the Boethian musical encyclopedia, which was addressed to philosophers, aligning it with musical reality and musicians. He combines *musica mundana* and *musica humana* with “animastic” music, distinguishing it clearly from the “organic” music produced by man on this Earth. Zarlino’s *musica instrumentalis* has moreover articulations lacking in the Boethian model, that incorporate the musical developments in the centuries separating Zarlino from Boethius: in particular “measured music,” which forms the subject of Part Three of *Le Istitutioni harmoniche*, on the rules of contrapuntal composition. Finally, the subject of *Le Istitutioni harmoniche* is *musica instrumentalis*, “music in particular” as distinct from the “music in universal,” *mundana* and *humana*, of the philosophers.

²⁰ Gioseffo Zarlino, *Le Istitutioni harmoniche* (Venice: [Francesco de’ Franceschi], 1558), p. 10.

²¹ Ibid.; see Kassler, *Inner Music*, p. 32.

²² Ibid., p. 11.



3. The division of music, from Gioseffo Zarlino, *Le Istitutioni harmoniche* (1558)

But what is “music in particular” for Zarlino? His *Istitutioni harmoniche* confirms a belief rooted in the Pythagorean-Boethian tradition: music “is a mathematical speculative science,”²³ one of the mathematical disciplines—along with arithmetic, geometry and astronomy—which in the tripartition of theoretical philosophy occupy an intermediate position between metaphysics and physics. The subject of music is the “sounding number,” where number is the form and sound the matter. As number, music is “subordinate” to arithmetic to the extent that arithmetic provides its subject, which is the number; as sound, music is “subordinate” to physics to the extent that sound is a quality of natural bodies. Music is, therefore, a “middle science” between mathematics and natural philosophy,²⁴ but it is

²³ Ibid., p. 20.

²⁴ Ibid., pp. 30-31.

mathematical rather than natural, the form (number) being more noble than the matter (sonorous quality). Musical science also has a practical part which cannot be separated from the theoretical: the distinction points up the difference between those who have an intellectual relationship with music (*musicus*) and those who have a corporeal relationship (composer, singer, player). Finally, unlike the rest of mathematics, music is a speculative science with a moral strain (“*musica non modo speculationi verum etiam moralitati coniuncta est*,” “music is tied not only to speculation but also to morals,” Boethius says in his *De musica*), given its power to move the soul to different passions.²⁵

Zarlino’s musical encyclopedia is not an isolated case in the Renaissance. In his *De musica* (1577) Francisco de Salinas (1513-1590) revises the Boethian tripartition in his “*musica trimembris*.” at the two extremes, he places music which moves only the sense (“*musica irrationalis*”) and music which moves only the intellect (“*musica intellegibilis*,”) mediated by music that moves the intellect and the sense together (“*musica instrumentalis*,”) intimating at the greater perfection of the latter over the two other genres of music.²⁶ Salinas then leaves sensible music to irrational creatures, intelligible music “*philosophis et astronomis*” (“to philosophers and astronomers,”) and offers up to the musical theorist ‘*musica instrumentalis*’, split into ‘*theorica*’ and ‘*practica*’, and enriched, vis-a-vis Zarlino’s *Istitutioni*, by a substantial part on rhythm (three of the seven books of *De musica*) based on St Augustine’s *De musica*.

Zarlino and Salinas are professional musicians and leave it to the speculative musicians—“*philosophis et astronomis*”—to adapt the new theory of “music in particular” to the “music in universal” engendered by the reformed cosmos of the Moderns. The two musics, ‘*instrumentalis*’ and ‘*mundana*’, are brought together in a book on astronomy, *Harmonices mundi libri quinque* (1619), by Johannes Kepler (1571-1630). The last three treatises of a book God waited six thousand years for, rework the Boethian tripartition for students of astronomy. Boethius’ tripartite music becomes in Kepler a single tripartite science of the harmony generated by the movement of voices (*musica instrumentalis*), the movement of Nature (*musica humana* and *astrologica*) and by the movement of the planets (*musica mundana*).²⁷

Boethius’ *De institutione musica* provides the Renaissance with another idea, pointed up by Zarlino : the power of music to arouse various passions in man. The obscure, emotional side of music has found an outlet in its long-lasting tie with the literary disciplines, especially poetry and rhetoric,

²⁵ Boethius, *De musica*, I, 1; Zarlino, *Istitutioni*, p. 8 and Part II, pp. 7-9.

²⁶ Francisco de Salinas, *De musica libri septem* (Salamanca: Mathias Gastius, 1577; reprint ed., Kassel und Basel: Bärenreiter, 1958), pp. 1-2.

²⁷ See Section 7 in this Introduction and Dickreiter’s piece in this Collection.

bearing witness to the complex articulations of the conceptual structure of musical science. One archetype of the second genre of music is Orpheus, whom Renaissance syncretism places beside Pythagoras. In his *Hebdomades, sive septem de Septenario libri* (1589), Fabio Paolini (1535-1605) includes the two traditions, mathematical and poetical, in a somewhat singular encyclopedia of the contemplative disciplines.²⁸ Paolini unifies the disciplines of the trivium in a single poetical-rhetorical art (Book I *De poetica atque oratoria facultate*), reworks the quadrivium by organizing it around the tripartite music of Boethius (II *De musica*; III *De humani animi sapientia, sive musica et harmonia*; IV *De astrologia*) which he subsumes under arithmetic (V *De arithmetica ideali*), and closes the ‘divine septenary’ of knowledge with magic (VI *De natura mysteriis*) and theology (VII *De theologia*). The tripartite music mediates the mysteries of theology and of ideal numbers with the power of poetical-rhetorical discourse, and it is this unity which generates the emotional power of music, the extraordinary effects of the song of Orpheus, the most perfect musician (*musicus perfectissimus*).

In the course of the 17th century the ‘two musics’, mathematical and poetical, which the Renaissance encyclopedia harmonized, start to draw apart. The ‘rhetorization’ of musical language in Baroque music widened the gap between the two cultures, the scientific and the humanistic, which by the 18th century were well on the road toward the final diaspora. However, the 17th century is not only the age of the mechanical world-view and of the *Affektenlehre*, it is also the age of speculative encyclopedism, of the attempts to construct a systematic encyclopedia of knowledge as a mirror of universal harmony and a means for man’s regeneration. The science of the musical characters of the world in the Baroque age is the embleme for absolute knowledge: the universal art of music (*musurgia universalis*) is both the science of sciences (*encyclopedia*) and the technique of combination and calculation applied to musical composition.²⁹ The idea of music as a metaphor of the encyclopedia and as an artificial language runs through the whole of the 17th century. The century opens with the rebirth of Augustinian *harmonie universelle*, which Mersenne links to the plan to reduce music to an “algebra of sounds” and to a “method for composing the best melodies possible,” and closes with the pansophic notes of Leibniz’s *characteristica* and the universalistic ideals of his encyclopedism.³⁰ For Leib-

²⁸ Fabio Paolini, *Hebdomades sive Septem de Septenario libri* (Venice: Francesco dei Franceschi, 1589); see Daniel P. Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute/University of London, 1958), pp. 126-144, and Section 6 in this Introduction.

²⁹ See Eberhard Knobloch, “Musurgia Universalis: Unknown Combinatorial Studies in the Age of Baroque Absolutism,” *History of Science* 38 (1979): 258-275.

³⁰ See Eberhard Knobloch, “Harmony and Cosmos: Mathematics Serving a Teleological Understanding of the World,” *Physis* 32 (1995): 55-89.

niz, founding an encyclopedia capable of uniting all the sciences and arts known to man and defining the universal “characters” of the world are closely linked projects. The characters of the world are for Leibniz prime numbers and musical intervals (tones and semitones), which confer on artificial language the elegance required by the pre-established harmony of signs and meanings, of physical and mental order.³¹ In the second half of the 18th century Kant’s work still bears witness to the close relationship between the idea of the cosmos and the encyclopedia, merged in the concept of harmony. “The starry sky above me” (*musica mundana*) and “the moral law within me” (*musica humana*, *inner music*) are the premise for Kant’s architectonics of Reason as harmonious connection between the sciences, which Romantic culture in Germany will link to the idea of the harmony of the world.³² Meanwhile, the dispute between Jean-Philippe Rameau (1683-1764) and the *philosophes* has already decreed the separation between the ‘two musics’ begun a century before. Rameau still sees the origin and the foundation of sciences in the mathematical laws of harmony engendered by Nature.³³ Rameau’s mirror image is Jean-Jacques Rousseau (1712-1778). Rousseau’s ‘cri animal’ mirrors Rameau’s ‘corps sonore’, but instead of generating the musical archetypes of scientific knowledge, it expresses the passions of the soul as the distinctive trait of human nature.

3 *Who is a musician?*

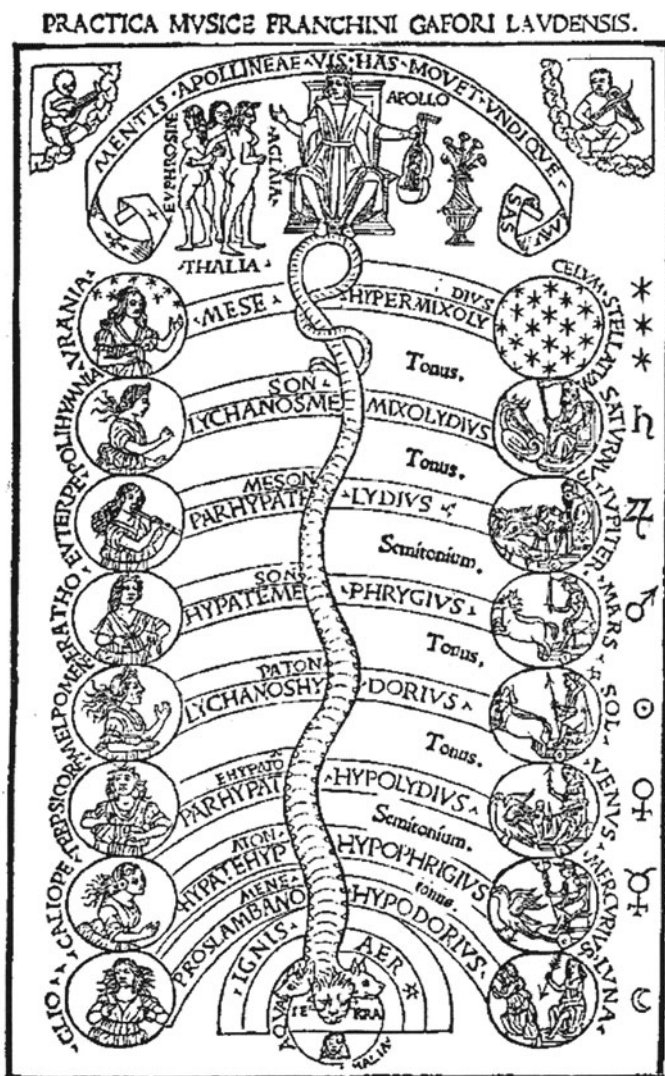
The idealization of music is mirrored in the idealization of the musician within the tradition of speculative music. The frontispiece of the *Practica musicae* (1496) by Franchino Gaffurio (1451-1522) is graced by an engraving idealizing the musician and his work through the restoration of an ancient tradition. (Figure 4) The engraving seeks to point out the cosmological dimension of musical creation to scholars and all those with a practical relationship with music, to whom Gaffurio’s treatise is addressed. Apollo on his throne is the demiurge of a living and harmonic universe, the *Musicus* who infuses his Creation with life and movement. Ministers of the Musagete are the minds, bodies and musical instruments of the Muses, who conduct the vocal motions of celestial bodies from the starry sky on high to the Earth below. The divine Musician communicates to Earth its

³¹ Daniel P. Walker, “Leibniz and Language,” *Journal of the Warburg and Courtauld Institutes* 35 (1972): 294-307, also printed in Daniel P. Walker, *Music, Spirit, and Language in the Renaissance*, ed. Penelope Gouk (London: Variorum Reprints, 1985).

³² See Leo Spitzer, *Classical and Christian Ideas of World Harmony: Prolegomena to the Word ‘Stimmung’*, ed. Anna Granville Hatcher (Baltimore: Johns Hopkins, 1963).

³³ Thomas Christensen, *Rameau and Musical Thought in the Enlightenment* (Cambridge: Cambridge University Press, 1993).

own measured rhythm through the coils of a dragon which symbolizes Time and which, on Earth, takes on three faces: one for the past, one for the present and one for the future.³⁴ The plate is not simply the musical rendering of the Pythagorean and Platonic tradition of 'God the geometer', it is also the model that informs other dimensions of music, mythological and worldly, well known to Renaissance culture.



4. Apollo and wordly music, from Franchino Gaffurius, *Practica musice* (1496)

³⁴ James Haar, "The Frontispiece of Gaffurius's *Practica musice* (1496)," *Renaissance Quarterly* 27 (1974): 7-22; see, also, Palisca, *Humanism*, pp. 171-174.

Gaffurio introduces the second representation of the *musicus* in a famous engraving in the *Theorica musice* (1492): it is the Iubal-Pythagoras couple, inventors of consonance. (Figure 1) The cosmographical mystery is revealed by the *prisci musici*, who through reason and experiment discover the mathematical and musical laws of Creation. The unwitting ministers of the *musici* are the blacksmiths, whose hammers strike out the sounds on the anvil that conceal the law of the universe, passed down under the veil of a fable.³⁵ The *prisci musici* are therefore also *prisci philosophi*, representatives of a noble genealogy which includes Orpheus, *priscus theologus* and *musicus*, who precedes Pythagoras.³⁶ An allegory for the origin of music until the 18th century, the fable of Pythagoras introduces into musical culture the dichotomy between *musica theorica* and *musica practica*, between theoreticians and practitioners. The engraving of the *Margarita Philosophica* by Gregor Reisch replaces Gaffurio's blacksmiths with the *ensemble* of instrumentalists to the right of the mythical inventor of the consonances.³⁷

A third engraving in the *De harmonia musicorum instrumentorum* (1518) shows Gaffurio in the act of teaching music *ex cathedra* to the *discipuli*: this is the secular dimension of *musicus*, after the divine and the mythological. (Figure 5) Chapter 33 "Quid sit musicus" ("Who is a musician?") in the first book of the *De institutione musica* by Boethius established for the centuries to come the musician's cultural and social primacy in the hierarchy of musical values: the true musician is not a slave to practice and masters it through speculation, the citharist and the poet do not take their name from the discipline because their mechanical (*citharoedus*) or instinctive (*poeta*) activity inhibits their capacity for judgement.³⁸ The *musicus* is therefore the theorist who since the 12th century of the Christian era has been teaching music at the university, the keeper of the tradition born in the workshop of the mythical blacksmiths. He passes on musical culture through oral and written teachings, tracing the changing rules of musical praxis back to the mathematico-musical laws of creation. His archetype is the Pythagorean-Boethian *musicus*, who has an intellectual relationship with music; his ministers and town-criers are the singers and composers, unaware of the causes of art and unworthy of the name of *musici*; his literary genre is the speculative musical treatise, whose centuries-

³⁵ Palisca, *Humanism*, pp. 227-229.

³⁶ Daniel P. Walker, "Orpheus the Theologian and Renaissance Platonists," *Journal of the Warburg and Courtauld Institutes* 16 (1953): 100-120, also printed in Daniel P. Walker, *The Ancient Theology: Studies in Christian Platonism from the Fifteenth to the Eighteenth Century* (London: G. Duckworth & Co., 1972), pp. 22-41.

³⁷ Gregor Reisch, *Margarita Philosophica* (Basel: Sebastianum Henricpetri, 1583), p. 342.

³⁸ Boethius, *De musica*, I, 34.

old tradition is the ideal music history over and above which run the various histories of music in the different countries.



5. The musician, from Franchino Gaffurio, *De harmonia musicorum instrumentorum* (1518)

In the Renaissance, changes in musical language and the rediscovery of Greek and Latin musical sources are the ground for the rebirth and metamorphosis of the Boethian *musicus*. The Renaissance image of the *musicus* is sculpted in two literary masterpieces of Renaissance musical literature: *Fronimo* (1568) by Vincenzo Galilei and *Dimostrazioni harmoniche* (1571) by Gioseffo Zarlino, two musical dialogues set respectively in the bucolic country backwaters of academic painters and men of letters, and in the Venice that in April 1562 was to give a solemn welcome to the corteo of Alfonso II, Duke of Ferrara.

A Franciscan hailing from Chioggia, Gioseffo Zarlino, who had already published the *Istitutioni harmoniche* (1558), ran the Marciana chapel from 1565, after Cipriano de Rore (ca. 1516-1565) and their teacher Adrian Willaert (ca. 1490-1562). The *Dimostrazioni* recount how to the Venetian house of the sick Willaert came Zarlino, Francesco dalla Viola (beginning of 16th century-1568), Ferrarese ducal chapel master, and Claudio Merulo (1533-1604), organist at San Marco: on the one side the *musicus*, on the other the *practici*. The dialogue begins with the unexpected arrival of a “worthy and honoured foreign gentleman,” “Desiderio di Nazione Lombardo da Pavia,” antonomasia of the “natural desire to know” of the *incipit*

to Aristotle's *Metaphysics*.³⁹ *Desiderio* takes "great delight" in music, but is above all interested in theoretical problems, having read, besides the Moderns, "many Greek and Latin authors, who worked with Music."⁴⁰ The relationship between ancient theory and modern musical practice, engendered by the 'natural desire to know', is the *fiat* of the five days of a dialogue that fires the conversation between theorist and practitioners with literary dignity and demonstrative rigour. At the top of the new hierarchy, the *musicus* (Messer Gioseffo) leads the learned conversation: like the *Humanist* (*Desiderio*) he can read the Greek and Latin authors in the original, like the *practici* (Adriano, Claudio and Francesco) he knows the rules of musical praxis and is able to demonstrate them. The title *Dimostrationsi* underlines the application of the geometric method to music, which the recent editions of the *Commentarii* of Proclus in *primum Euclidis Elementorum* (1560) and of the *Sectio canonis* (1557), attributed to Euclid, made topical. Unlike Boethius' *musicus*, Zarlino is the "perfect musician," combining as he does both scientific and Humanistic culture and the musical competence of professional musicians.⁴¹

Three years prior to the *Dimostrationsi*, Girolamo Scotto's press in Venice had printed *Fronimo* by Vincenzo Galilei (ca. 1525-1591). Unlike Zarlino, Galilei is neither a member of a religious order nor a musical chapel master. At first, he is a lutenist who becomes a member of the entourage of the Bardi Counts in Florence; they then send him to Venice to complete his musical education on a theoretical level under Zarlino. His encounter with a Humanist, Girolamo Mei (1519-1594), a learned scholar of Greek musical theory, marks the break in the relationship between Galilei and Zarlino and the beginning of the dispute that will separate them unto their deaths.⁴² Unlike the *Dimostrationsi*, *Fronimo*'s characters have no historical background, their names stand for the chief virtue of their activity. *Fronimo*, depicted in the act of tuning his lute in an idyllic countryside,⁴³ is the possessor of *phrónesis*, prudence or temperance, virtue on the calculating side of the rational soul, the object of which is not necessary truths but the general rules for the specific case: the principles of writing musical scores (*intavolatura*) for the lute around which the dialogue is centred. *Fronimo* talks to *Eumatio*, the possessor of *eumatia*, a good disposition towards learning. The rhetoric of the Galileian dialogue confers lit-

³⁹ Gioseffo Zarlino, *Dimostrationsi Harmoniche* (Venice: Francesco dei Franceschi Senese, 1571), p. 2.

⁴⁰ Ibid.

⁴¹ See my "Desiderio" in the present Collection.

⁴² See Section 6 of this Introduction.

⁴³ Vincenzo Galilei, *Fronimo... Dialogo sopra l'arte del bene intavolare et rettamente sonare la musica negli strumenti artificiali si di corde come di fiato, & in particolare nel liuto. Nuovamente ristampato...* (Venice: appresso l'Herede di Girolamo Scotto, 1584; first ed., Venice: Girolamo Scotto, 1568), p. 3.

erary dignity on the art of writing scores, not a base mechanical art but a praxis ennobled by reason.⁴⁴ The quarrel between Zarlino, the ‘rationalist’, and Galilei, the ‘empiricist’, between the Euclid and the Pericles of Renaissance music, has as its premise the variety of roles of the *musicus* on the Renaissance scene: on the one hand, the post-Boethian theorist, who reforms from within the speculative tradition which was born of sacred vocal polyphony with the Humanist and mathematical paradigm; on the other, the practical musician, who reappraises the knowledge and experience of instrumentalists, becoming the theorist of a new musical language, the expression of academic culture and the taste of courtly society.

In the course of the 17th century the gestation of modern musical theory (the *Seconda Prattica*), which succeeds Zarlino’s perfection of the theory of vocal counterpoint (the *Prima Prattica*), once again brings to the fore the break between the philosopher and musical practitioners. A variant of the Boethian *musicus* is now the mathematician and natural philosopher: Descartes, who relegates Zarlino to practitioner in his *Compendium musicae*; Kepler, who ennoble the polyphony unknown to the Ancients with the reformed astronomy of the Moderns; Galileo, who reinterprets Gaffurio’s engraving on the discovery of consonance and recycles it in his mechanics of elastic bodies.⁴⁵ This separation of the competences in music exists alongside the contemporary image of the *musicus* in the age of speculative encyclopedism. Mersenne’s ideal of the *musicus* as universal man, someone who must know all the sciences in order to be able to interpret the secret relationship God has established between sounds and the soul,⁴⁶ is the mirror image of the Baroque encyclopedia as expression of *musurgia universalis*. The 17th century conception of the *musicus perfectissimus* can be seen in the polyhedral knowledge of the “Complete Musician” that William Brouncker (1620-1684), future President of the Royal Society, lists in his Preface to Descartes’ *Compendium of Musick* (1653):

... to a Complete Musitian (please you, to understand Him to be such, as hath not only Nibbled at, but swallowed the whole Theory of Musick, i.e. haveing profoundly speculated the Pythagorean Scheme of the various Sounds arising from Various Hammers, beaten on an Anvill, respective to their different Weights, doth clearly and distinctly understand as well the Arithmetical, as Geomtrical [sic] Proportions of Consonances, and Dissonances: for, it is not the mere Practical Organist, that can deserve that Noble Attribute) is required a more than superficial insight into all kinds of Humane Learning. For, he must be a Physiologist, that He may demonstrate the Creation, Nature, Properties, and Effects of a Natural Sound. A Philologer, to inquire into the first Invention, Institution, and succeeding Propa-

⁴⁴ Ibid., pp. 1, 8.

⁴⁵ See the Section ‘Reconceiving music’ in this Introduction.

⁴⁶ Robert Lenoble, *Mersenne ou la naissance du mécanisme* (Paris: J. Vrin, 1971²), pp. 522-531.

gation of an Artificial Sound, or Musick. An Arithmetician, to be able to explaine the Causes of Motions Harmonical, by Numbers, and declare the Mysteries of the new Algebraical Musick. A Geometrician; to evince, in great variety, the Original of Intervalls Conson-dissonant, by the Geometrical, Algebraical, Mechanical Division of a Monochord. A Poet; to conform his Thoughts and Words, to the Lawes of praecise Numbers, and distinguish the Euphonic of Vowells and Syllables. A Mecanique; to know the exquisite Structure or Fabrick of all Musical Instruments, Winde, Stringed, or Tympanous aliàs Pulsatile. A Metallist; to explore the different Contemperations of Barytonous and Oxytonous, or Grave and Acute toned Metals, in order to the Casting of tuneable Bells, for Chimes, &c. An Anatomist; to satisfie concerning the Manner, and Organs of the sense of Hearing. A Melothetick, to lay down a demonstrative method for Composing, or Setting of all Tunes, and Ayres. And, lastly, He must be so far a Magician, as to excite Wonder, with reducing into Practice the Thaumaturgical, or admirable Secrets of Musick: I meane, the Sympathies and Antipathies betwixt Consounds and Dissounds; the Medico-magical Virtues of Harmonious Notes (instanced in the Cure of Sauls Melancholy fitts, and the prodigious Venome of the Tarantula, &c.) the Creation of Echoes, wether Monophone, or Polyphone, i.e. single or Multiplied, together with the Figure of Buildings, and arched Rocks, neer Rivers, Dales, or Woods, requisite to the multiplyed Reverberations of Sounds; the Artifice of Otcoustick Tubes, or Auricular Meanders, for the strengthening, continuation, and remote transvection of weake sounds, and the mitigation of strong; the Model of Auto-phonus, or speaking Statues; and finally, the Cryptological Musick, whereby the secret Conceptions of the mind may be, by the Language of inarticulate Sounds, communicated to a Friend, at a good distance.⁴⁷

The list reads as an ideal manifesto for the supposed musical aims of the Royal Society. This 17th century image of the ‘Complete Musician’ is on the other hand reminiscent of the Boethian primacy of the man of science over the “practical organist;” as such, it is not intended to reform but rather to preserve the rift between modern music scientists and music composers and players. The dismembered parts of the ‘perfect musician’ were recomposed one last time in the first half of the 18th century in Jean-Philippe Rameau. Then Romantic culture will redraw musical values, replacing the *musicus* of Pythagorean-Boethian inspiration, reassumed by Rameau, with the gifted composer, unwitting demiurge of the musical work of art.

⁴⁷ *Renatus Des-Cartes Excellent Compendium of Musick: With Necessary and Judicious Animadversions thereupon, by a Person of Honour* (London: Printed by Thomas Harper, for Humphrey Moseley, 1653), “The Stationer to the Ingenious Reader;” on this English edition of the *Compendium*, see Descartes, *Abrégé de musique*, Edition nouvelle, traduction, présentation et notes par Frédéric de Buzon (Paris: Presses Universitaires de France, 1987), pp. 37-40.

Recollecting Music

4 Sources and institutions

The recovery of Greek musical sources began not in the Latin West but with the Byzantines who had direct access to the originals. Around the 10th century a circle of learned musicologists grew up in Byzantium, to whom all the Greek musical codices known today can be traced: the *Sectio canonis* attributed to Euclid, the *Harmonica* by Aristoxenus and the fragments of a treatise of his on rhythm, the treatises *De musica* by Aristides Quintilianus and Plutarch, the *Enchiridion* by Nicomachus, the *Introductio harmonica* of Gaudentius and Cleonides, the *Harmonica* by Ptolemy with the comment by Porphyry, the *Introductiones musicae* by Alypius, Baccheius and Dionysius, and finally some anonymous texts (later called *Anonymi Bellermanniani*) and some fragments.⁴⁸ The recovery and reception of this literature by Westerns can be ascribed to learned Byzantines of the 12th, 13th and 14th centuries, such as Maximus Planudes or Manuel Bryennius (whose musical synthesis was later assimilated to ancient writings), and to the Byzantine and Italian collectors of the 15th century. It was in Venice, with its favorable geographical, economic and political position vis-a-vis Byzantium, that at the end of the 15th century all the Byzantine musical codices could be found, which already belonged to the Venetian patrician and collector Francesco Barbaro, the Cardinal Bessarione and Giorgio Valla, the first to translate Cleonides and Euclid (1497).⁴⁹ The library of the San Marco convent in the Florence of Cosimo de' Medici and the Vatican library in the Rome of Pope Nicolas V (1447-1455) and his immediate successors were, like the Marciana in Venice, the first public libraries to house codices of the ancient Greek writers on music.⁵⁰

The Greek and late-Roman musical sources did not include musical examples that could be reproduced by the musicians of the 15th or 16th century. The only *repertoire* of ancient music were a few hymns of Hellenistic times which had passed unnoticed until Girolamo Mei sent a copy in 1579 to Vincenzo Galilei, who published them in their original form.⁵¹ Ancient music was not the instrumental music practiced in Greece, but the intellectual music conceived and written by the philosophers, mathematicians and musical theorists of antiquity, later preserved in the musical codices

⁴⁸ F. Alberto Gallo, "Die Kenntnis der griechischen Theoretikerquellen in der italienischen Renaissance," in *Geschichte der Musiktheorie*, 10 vols., *Italienische Musiktheorie im 16. und 17. Jahrhundert* (Darmstadt: Wissenschaftliche Buchgesellschaft, 1989), 7:7-38, pp. 10-11.

⁴⁹ Ibid., pp. 13-18.

⁵⁰ Palisca, *Humanism*, pp. 23-50.

⁵¹ Ibid., p. 450.

arrived in Italy from Byzantium. *Renaissance music*, i.e. music imbued with Greek musical culture, affected the *music of the Renaissance* via readings and commentaries of the ancient theories of music in the era of modern music.⁵² The paradox may explain the rift between the world of culture and the world of musical professionals which marked the early phase of Renaissance music. At the end of the 15th century the composer, the chapel master or the musical theorist trained in the Scholastic tradition of music theory were not involved in the work of recovering, translating and interpreting the Greek musical treatises undertaken by the humanists, philosophers and men of culture, who saw in music one of the theoretical sciences of the encyclopedia, or a literary discipline to be placed alongside rhetoric and poetry. Franchino Gaffurio—composer, chapel master and then also public lecturer in music at the university of Milan established by Ludovico il Moro—healed this rift by promoting a dialogue between music and culture which left its mark on the second phase of the musical Renaissance.⁵³ Gaffurio was the first musical humanist to try to study the Greek musical texts. Ignorance of the language, which had accounted for the delay of the Latin Middle Age vis-a-vis the Judaic, Arabic and especially Byzantine culture in understanding Greek music, was overcome by Gaffurio's contacts with Humanist circles to whom he entrusted, in the persons of Gianfrancesco Burana and Nicolò Leonicensio, the translations from the Greek: Aristides Quintilianus, the so-called Anonymi of Beller-mann, Bryennius and perhaps Bacchius (Burana), and Ptolemy (Leoniceno). The musical writings of Gaffurio, from *Theorica musice* (1492) to *De harmonia musicorum instrumentorum* (written in 1500, published in 1518), show Gaffurio's increasing familiarity with the ancient theorists: while only mentioned in the First Book of the *Theorica* inspired by Boethius, in the *De harmonia* they put forward the main themes of the treatise.⁵⁴ The Humanistic dialogue between musicians and men of letters marked a turning point in the history of Italian musical culture. The controversy which between the 15th and 16th centuries pitched Ramos de Pareja (ca. 1440-after 1491) and Giovanni Spataro (ca. 1458-1541) against Gaffurio and Niccolò Burzio (ca. 1450-1518) is symptomatic of the intellectual and social upheaval wrought on the world of musicians by the introduction of classical culture: on the one hand the theorists trained in the linguistic and cultural models of Scholastic treatise writing, on the other the musical Humanists who renewed the forms of musical literature to bring it into line with the new literary paradigm.⁵⁵ "To the authority of Franchino Gaffurio," Gioseffo Zarlino himself would appeal in his *Istitutioni harmoniche*. Zar-

⁵² Ibid., p. 5.

⁵³ Gallo, "Die Kenntnis," pp. 19-22; Palisca, *Humanism*, pp. 191-225.

⁵⁴ Gallo, "Die Kenntnis," p. 22.

⁵⁵ Palisca, *Humanism*, pp. 230-235.

lino is credited with having arranged the list of the books on music in the *Summa librorum* (1559), the publishing program of the Accademia Veneziana that “the law giver of music” was a member of. The list associates the ancient musical theorists (Ptolemy, Porphyry, Euclid, Aristides Quintilianus) with the modern theorists (Fogliano, Faber Stapulensis, Francesco Giorgi Veneto), hinting at the unity and continuity of Renaissance musical culture with its ancient past, that had turned up with the Greek musical codices in Venice a century before.⁵⁶

The distinction between speculative and practical music is the premise to the presence of music in cultural institutions. The distinction helps account for the variety of forms music assumed in European medieval universities. The university allowed different levels of musical activity often overlapping: from vocal and instrumental execution to oral teaching and written composition. At one extreme there was music as entertainment: from the instrumental ensemble to dance and the songs of the symposium; at the other extreme there was the *ars musica*, music as quadrivial discipline taught in the Faculty of Arts with arithmetic, geometry and astronomy. Between the two extremes there were other intermediate levels: music in function of the periodical events of the community of *doctores* and *scholares*; oral teaching of the elementary rules of plainchant in the musical chapels annexed to monasteries and cathedrals; finally musical treatise writing oriented more towards the theory of contemporary musical praxis than to the cosmological and mathematical foundation of the science of music.⁵⁷

At the beginning of the 13th century the *ars musica* taught in the European Universities is no different to that taught in the schools of the monasteries and cathedrals: reading the Books, usually the first two, of *De institutione musicae* by Boethius, and *compendia* and *commenta* inspired by it—as later (13th century) the *Musica speculativa* by Jean de Murs (ca. 1290-ca. 1351), widely read throughout Europe and still taught in the 18th century at the University of Cracow. A statute of the Faculty of Arts at the Universitas parisiensis in the mid-13th century records, however, a change in the programs of oral teaching which from 1255 to the beginning of the 14th century consisted primarily of *philosophia naturalis*.⁵⁸ Bearing musical witness to the growing spread of Aristotelianism are the roughly fifty copies of the first Latin translation of the *Problemata* attributed to Aris-

⁵⁶ Ian Fenlon, “Zarlino and the Accademia Venetiana,” in *Italian Academies of the Sixteenth Century*, ed. David S. Chambers and François Quiviger (London: The Warburg Institute/University of London, 1995), pp. 79-90, esp. 84-85.

⁵⁷ Michel Huglo, “The Study of Ancient Sources of Music Theory in the Medieval Universities,” in *Music Theory and Its Sources: Antiquity and the Middle Ages*, ed. André Barbera (Notre Dame, Indiana: University of Notre Dame Press, 1990), pp. 150-172.

⁵⁸ *Ibid.*, pp. 151-156.

totle, which Bartolomeo da Messina carried out between 1258 and 1266, sections 11 and 19 of which are the only two Greek texts of musical theory translated into Latin in the Middle Ages.⁵⁹ The move from Platonism to Aristotelianism is accompanied in the same period by the introduction of measured-chant treatises into the *curriculum studiorum* of Europe's leading universities: *De mensurabili musica* by Johannes de Garlandia and his successors, the *Anonimo* of 1279, Franco and Anonimo IV, written between 1260 and 1285,⁶⁰ followed in the 14th century by the musical treatises of Philippe de Vitry (1291-1361) and de Murs in Paris, of Marchetto (ca. 1274-1326) and Prosdocimo de Beldemandis in Padua (ca. 1380-1428), whose theoretical production coincides with his teaching in the University of Padua in the second and third decades of the 1400s.

The tripartite harmony of Boethius, however, long remained the main catalyzer of the forms of musical speculation in universities. The anonymous *Questions* on music proposed at the end of the 14th century in a university course of the late Scholastic, attributed to Biagio Pelacani, *magister artium* in Padua, Bologna and Parma, illustrate a recurrent phenomenon in the history of university musical culture: the Boethian system is used to review all the aspects of the discipline and adapt them to contemporary science and philosophy.⁶¹ The second *quaestio* "Utrum sonus sit subiectum in musica" follows Boethian *musica trimembris*, and the comment touches on cosmological, mathematical and natural issues: the structure of the skies, the four elements, the mind-body relation, the action of qualities, the problem of movement, the nature and propagation of sound, the theory of consonance, and the concept of proportion that encompasses all: "musica in ratione numerorum consistit," music is the science of the mathematical proportions between the parts of a whole, natural or metaphysical, sonorous or mental. At the height of the Renaissance Boethius is still a studied author, translated and collected.⁶² The case of the Jesuit schools is significant. The primacy of mathematics in the *ratio studiorum* revised by Cristoph Clavius (1537-1612) can be seen in the Renaissance tradition of *compendia* of Boethius' *De institutione musicae*, destined to be taught orally: *Musica demonstrata* (1496 and 1551) by Jacobus Faber Stapulensis (Jacques Le Febvre d'Étaples) and *Musicae traditiones* (1575) by Fran-

⁵⁹ F. Alberto Gallo, "Greek Text and Latin Translation of the Aristotelian Musical Problems: A Preliminary Account of the Sources," in *Music Theory*, pp. 190-196.

⁶⁰ Jeremy Yudkin, "The Influence of Aristotle on French University Music Texts," in *Music Theory*, pp. 173-189.

⁶¹ See Cecilia Panti, "Una fonte della 'Declaratio musicae disciplinae' di Ugolino da Orvieto: quattro anonime 'Quaestiones' della tarda scolastica," *Rivista Italiana di Musicologia* 24 (1989): 3-47.

⁶² Claude V. Palisca, "Boethius in the Renaissance," in *Music Theory*, pp. 259-280.

cesco Maurolico (1494-1575), forerunners of the *Compendium musicae* (1618) by René Descartes.⁶³

The Renaissance complicated the teaching of musical theory in cultural institutions. Alongside and in competition with the Universities, state or private, the Academies grew up as institutions halfway between private and public, designed to culturally educate the noble offspring of the ruling classes in the towns. At the Italian Academies of the 16th century music was usually conceived of as a speculative discipline within the encyclopedia of the liberal arts. Rarely did musical practice alone, vocal and instrumental, justify the setting up of a musical institution created as living metaphor of the Parnassus symbolized by the Muses and by Apollo Musagete.⁶⁴ This nonetheless was the case both of the Accademia degli Unisoni in Perugia⁶⁵ and of the Accademia Filarmonica founded in Verona in 1543.⁶⁶ The latter cultivated musical divertissements leaving Pietro Pontio (1532-1595) the job of arguing in his *Dialogo della Theorica e Pratica di musica* (1595), dedicated to the Veronese Academy, the primacy of active music over contemplative music. However the Accademia Veneta or della Fama, founded by Federico Badoer in 1557 and renowned for its encyclopedic organization of knowledge, gave over one of the four rooms of the "Council of the Sciences," the room "de' Mathematici" ("of the Mathematicians,") to the science of music. It is not astonishing to find Gioseffo Zarlino here in this room. Zarlino's presence in the Venetian Academy is attested by two significant cultural facts: the list of music books, both ancient and modern, which the Academy intended to publish,⁶⁷ and the *Dimostrazioni harmoniche* published by Zarlino after the dissolution of the Fama, whose most singular scientific legacy they are.⁶⁸ Zarlino was the link between the Accademia della Fama and the Accademia degli Uranici, established in 1587 in Venice by Fabio Paolini. Professor of Greek and Latin in San Marco, Paolini is the author of a sophisticated synthesis of the musical Renaissance; his academic orations on music reconcile Greek Arcadia and Virgilian verse, Platonism and Aristotelianism, contemplation and practice, and prescribe a model of musical composition, the monodic song accompanied by simple harmonies, which recalls con-

⁶³ See my "Descartes" in the present Collection.

⁶⁴ Marc Fumaroli, "Academia, Arcadia, Parnassus: trois lieux allégoriques de l'éloge du loisir lettré," in *Italian Academies*, pp. 15-35.

⁶⁵ Allan Atlas, "The Accademia degli Unisoni: A Music Academy in Renaissance Perugia," in *A Musical Offering: Essays in Honor of Martin Bernstein*, ed. Edward H. Clinkscale and Claire Brook (New York: Pendragon Press, 1977), pp. 5-23.

⁶⁶ See Fenlon, "Zarlino," p. 80.

⁶⁷ *Summa Librorum quos in omnibus scientijs in lucem emittet Academia Veneta* (Venice: in Academia Veneta, 1559); see Fenlon, "Zarlino," pp. 84-85.

⁶⁸ See my "Desiderio" in the present Collection.

temporary experiences.⁶⁹ The nostalgic myth of ancient Greek music, academic and literary, was renewed through musical reform in both the Florentine literary and musical academies of the second half of the 16th century—from the Accademia degli Alterati⁷⁰ to the Camerata fiorentina—⁷¹ and in the French academies of the late 16th century:⁷² the “maravigliosi effetti della musica antica” became in the Italian and French academies the forerunner of opera and the *musique mesurée à l'antique*.

The work of Marin Mersenne (1588-1648) is the main element in the continuity between Antoine Baïf and Jacques Maudit's Académie de poésie et de musique (1570-1585) and the modern academies, which have a decidedly scientific outlook later ratified by the foundation of the Académie royale des sciences.⁷³ The 17th century encyclopedic ideal is embodied in the scientific research planned and discussed within the academies, and together with optics, mechanics or astronomy, music was one of the subjects investigated by the natural philosophers at the Cimento, Royal Society and Académie des Sciences. It was as part of the scientific research of the Paris Academy of Science that the problem of the origin and foundation of harmony, with which our history began, was finally tackled in modern terms. The Pythagorean paradox of different sounds engendered by the single string that encapsulates them became the paradox of different vibrating motions in the whole vibrating string, able to engender, with its fundamental sound, the theoretically infinite series of its harmonics, whose frequency is a multiple of the fundamental frequency. This redefinition of the origin and foundation of harmony can be found in the *Mémoires* Joseph Sauveur (1653-1716) presented in 1701 to the Academicians of the French institution.⁷⁴ The *merveille* Fontenelle experienced on

⁶⁹ See Section 6 in this Introduction.

⁷⁰ Claude V. Palisca, “The Alterati of Florence, Pioneers in the Theory of Dramatic Music,” in *New Looks at Italian Opera: Essays in Honor of Donald J. Grout*, ed. William Austin (Ithaca, NY: Cornell University Press, 1968), pp. 9-38, also printed in Claude V. Palisca, *Studies in the History of Italian Music and Music Theory* (Oxford: Clarendon Press, 1994), pp. 408-431.

⁷¹ Claude V. Palisca, *The Florentine Camerata. Documentary Studies and Translations* (New Haven and London: Yale University Press, 1989).

⁷² Frances A. Yates, *The French Academies of the Sixteenth Century* (London: The Warburg Institute/University of London, 1947; reprint ed., London and New York: Routledge, 1988).

⁷³ *Ibid.*, pp. 275-316; see, also, Albert Cohen, *Music in the French Royal Academy of Sciences: A Study in the Evolution of Musical Thought* (Princeton, NJ: Princeton University Press, 1981).

⁷⁴ Joseph Sauveur, “Système général des intervalles des Sons, & son application à tous les Systèmes & à tous les Instrumens de Musique,” in *Histoire de l'Académie Royale des Sciences. Année 1701. Avec les Mémoires de Mathématique & de Physique, pour la même Année* (Amsterdam: Gerard Kuyper, 1707), pp. 390-482.

seeing and hearing Sauveur's demonstration⁷⁵ anticipated that of Jean-Philippe Rameau, who saw his own mathematical principle of harmony experimentally confirmed in the memoirs presented by Sauveur to the Académie des Sciences. And to the "Messieurs de l'Académie Royale des Sciences" Jean-Philippe Rameau addressed his own *Génération harmonique* (1737), prompted by 'Newtonian' experiments on the properties of sound, while his *Démonstration du principe de l'harmonie* (1750) was "Approuvée par Messieurs de l'Académie des Sciences," thereby bearing witness to the now century-old association of music and the modern academic institution.⁷⁶

5 Musical genre

From the 4th century BC to the mid-18th century the treatise on music is the literary genre that informs the intellectual identity of music, assigns it its place in the encyclopedia of knowledge and sets itself up as the sole repository of the discipline's historical memory. The *Historia musica* (1695) by Angelini Bontempi, perhaps the first book of music to link music and history in its title, is not in fact a history of music but a systematic description of musical theory articulated in theses and corollaries and rooted in the speculative musical tradition.⁷⁷ Bontempi entitles his treatise on musical theory *Historia* because treatises had always dealt with history: from Boethius, who reports the opinions of the Greek theorists, to Gaffurio and Zarlino, who discuss all previous musical treatise writing, through to Rameau who, via Zarlino, Descartes and Mersenne, sums up modern musical writing.

But what is a treatise on music? A student of the Greek musical codices has answered this question by using the metaphor of the onion: the critic continually tears away layers (amendments, additions, interpolations narrating the history of the codex) only to find others beneath; the answer to the question, however, does not lie in reaching the center but in giving each layer its own place in the history of the codex, in its *Rezeptionsgeschichte*.⁷⁸ The warning does not simply apply to the study of musical

⁷⁵ Bernard le Bovier de Fontenelle, "Sur un nouveau système de musique," in *Histoire de l'Académie Royale des Sciences. Année 1701*, pp. 155-175..

⁷⁶ See Christensen, *Rameau*, pp. 159-162.

⁷⁷ Giovanni Andrea Angelini Bontempi, *Historia Musica, nella quale si ha piena cognitione della Teorica e della Pratica antica della Musica Harmonica...* (Perugia: pel Costantini, 1695; reprint ed., Bologna: Forni, 1971).

⁷⁸ André Barbera, "Reconstructing Lost Byzantine Sources for MSS Vat. BAV gr. 2338 and Ven. BNM gr. VI.3: What is an Ancient Music Treatise?," in *Music Theory*, pp. 38-67, esp. 65.

codices but extends to the theory of the text,⁷⁹ is therefore an effective antidote to the periodical classificatory temptations inflicted on musical treatise writing, especially in the Middle Ages. From Gerhard Pietzsch to Lawrence Gushee, these classifications answer the question ‘what is a musical treatise?’ in terms of a ‘question of genre’: they transform the problem of the tradition of the text into the definition of models. These classifications try to order the extraordinary variety of musical treatises, ancient and medieval, by using different criteria—from the distinction between *musica theórica* and *musica practica*⁸⁰ to more complex and sophisticated categories: genre, style, public, and so on.⁸¹ They produce, however, a subtle distortion of the musical treatise: instead of being a live testimony to the culture of an era, the treatise is hemmed into a narrow enclosed space, helpful perhaps for the present-day scholar but foreign to the cultural beliefs of its Author. Music makes no exception to the medieval intellectual’s trust in the unitary structure of knowledge, the specificity of the discipline does not exclude its dependence on the principles of knowledge and the aim of understanding the theological truths, common to all the *artes*.⁸²

The same trust is shared by the Renaissance musical theorist who sees the treatise as a synthesis of ancient, medieval and modern musical culture. In Zarlino’s *Dimostrazioni*, “the natural desire to know” in the celebrated *incipit* of Aristotle’s *Metaphysics* wears the clothes of a foreign gentleman, “Desiderio da Pavia,” who in the role of reader of the ancient writers of music wants to resolve a doubt: how to reconcile the science of the Ancients with the music of the Moderns?⁸³ Reconciling theory and practice, reason and experience, is not just a technical problem of a few musical professionals but belongs to the whole of culture. The musical treatise stands witness to the faculty of music to contaminate culture, to change it and be changed by it. The dialogic genre of the *Dimostrazioni* is the rhetorical instrument that opens up the world of music to the Humanist interlocutor, charged with mediating communication between theorists and practitioners, reason and sense.⁸⁴ The Euclidean structure of the *Dimostra-*

⁷⁹ Thomas J. Mathiesen, “Ars Critica and Fata Libellorum: The Significance of Codicology to Text Critical Theory,” in *Music Theory*, pp. 19-37.

⁸⁰ Gerhard Pietzsch, *Die Klassifikation der Musik von Boethius bis Ugo da Orvieto* (Halle: M. Niemeyer, 1929; reprint ed., Darmstadt: Wissenschaftliche Buchgesellschaft, 1968).

⁸¹ Lawrence Gushee, “Questions of Genre in Medieval Treatises on Music,” in *Gattungen der Musik in Einzeldarstellungen. Gedenkschrift Leo Schrade*, ed. Wulf Arlt, Ernst Lichtenhahn and Hans Oesch (Bern-Munich: Francke Verlag, 1973), pp. 365-433.

⁸² Nancy van Deusen, *Theology and Music at the Early University. The case of Robert Grosseteste and Anonymus IV* (Leiden/New York/Köln: E.J. Brill, 1995), xiii.

⁸³ Zarlino, *Dimostrazioni*, p. 2.

⁸⁴ Klaus-Jürgen Sachs, “Boethius and the Judgement of the Ears: A Hidden Challenge in Medieval and Renaissance Music Theory,” in *The Second Sense. Studies in Hearing and Musical Judgement from Antiquity to the Seventeenth Century*, ed. Charles Burnett, Mi-

tioni harmoniche is, on the other hand, the contamination of musical theory with the method of scientific demonstration.⁸⁵ Aligning musical theory to the Euclidean paradigm is not imitation of an extraneous model but the updating of a mathematical discipline in the light of the successful geometrical method of the ancient mathematicians and Greek musicologists. These developments set the *Dimostrationi* and their Author in a precise historical and cultural context. The treatise stands witness to the active participation of Zarlino in the Venetian culture of the 1560s. The “translations from the Greek” commissioned by Franchino Gaffurio are re-born in Zarlino’s contacts with the Venetian and Lombard Humanistic circles. The relationships between Gaffurio and his colleague at the Milan university, the mathematician Luca Pacioli, live again in the contacts between Zarlino and “the modern mathematicians” at the University of Padua, open to the renaissance of mathematics by the teachings of Francesco Barozzi (1537-1604).⁸⁶ Zarlino’s membership in the Accademia della Fama links music to Federico Badoer’s project of cultural and political renewal, which continues in the Accademia degli Uranici via the musical interests of Fabio Paolini, who asks Zarlino for the musical codices of Marciana.

Is the musical treatise not a betrayal by the theorist of musical praxis, of the polyphonic choruses of the Cappella Marciana that Zarlino was Maestro of? Does not the science of the Ancients contradict the practice of the Moderns, or, vice versa, does not modern polyphony falsify the musical theory of the age of ancient monody? Desiderio’s doubt is the problem which from Gaffurio to Nicola Vicentino, from Zarlino to Vincenzo Galilei, and from Salinas to Descartes and Kepler runs through the pages of the Renaissance musical treatise. The theorists’ response to the unrepeatability of sonorous events and apparent lack of principles of musical praxis is to search for their intellectual archetypes. To Willaert, who can give no explanation for his own compositions, Zarlino answers with the demonstration learnt at the school of the ancient geometers.⁸⁷ The response of the theorist is not a betrayal of the work of men but its idealization: musical praxis *sub specie aeternitatis*, the affirmation of the unity of knowledge as

chael Fend and Penelope Gouk (London: The Warburg Institute/University of London, 1991), pp. 169-198.

⁸⁵ See Michael Fend, “Zarlino’s Versuch einer Axiomatisierung der Musiktheorie in den “Dimostrationi harmoniche” (1571),” *Musiktheorie* 4 (1989): 100-112.

⁸⁶ See Paolo Gozza, “La musica tra matematica e antica teologia,” in *Sapere e/è Potere. Discipline, dispute e professioni nell’Università medievale e moderna. Il caso bolognese a confronto*, 2 vols., *Verso un nuovo sistema del sapere*, ed. Andrea Cristiani (Bologna: Istituto per la Storia di Bologna, 1990), 2:217-238, and Ann Elisabeth Moyer, *Musica Scientia. Musical Scholarship in the Italian Renaissance* (Ithaca and London: Cornell University Press, 1992), pp. 126-134.

⁸⁷ Zarlino, *Dimostrationi*, p. 5; see my “Desiderio” in this Collection.

a mirror of universal harmony. And the distance that remains between the music produced by men and *the music* of the treatise is not fault of musical theorists alone but also of men of culture, their idea of reason and science, and the role assigned experience in cultural systems.

The musical treatise is not just the object of musicologists alone. Alongside the names of Gaffurio, Fogliano, Glareanus, Vicentino, Zarlino, Salinas, Vincenzo Galilei and Artusi, the Renaissance includes those of magicians, natural philosophers, mathematicians, astronomers: Marsilio Ficino, Faber Stapulensis, Giorgio Valla, Francesco Giorgi Veneto, Francesco Maurolico, René Descartes, Johannes Kepler, Simon Stevin and Marin Mersenne. In the 17th century the musical treatise stands witness to affirmation of the modern scientific paradigm: the *Elucidationes physicae* that Nicolas Poisson published in the margins of his French translation of the *Abrégé de musique* (1668) by Descartes reveals the intention to complete the mathematical demonstrations of the youthful Cartesian treatise with the experimental musical pages of Galileo's *Discourses* (1638);⁸⁸ the *Musica speculativa* (1670) by Pietro Mengoli, despite its traditional title, seeks to deduce musical theory from the mechanistic doctrines of sound and from the anatomy and physiology of hearing;⁸⁹ and the treatise *Del suono, de tremori armonici e dell'udito* (1679) by the Jesuit father Daniello Bartoli, in its very title points to the changes wrought in the musical treatise by modern experimental philosophy.⁹⁰ In the mid-1700s Jean-Philippe Rameau is the epitome of the musical treatise tradition which had begun in the 4th century B.C. If the *Traité de l'harmonie* of 1722 reworks Renaissance models, the *Génération harmonique* (1737) and the *Démonstration du principe de l'harmonie* (1750) speak the language of Newtonian science and are addressed to the *philosophes*, who include music in their scientific agenda.⁹¹ With the Illuminists the musical treatise is clarified, emended and simplified⁹² before being finally set aside and de-

⁸⁸ Nicolas Poisson, "Elucidationes Physicae in Cartesii Musicam," in *Traité de la mécanique composé par Monsieur Descartes. De plus l'abregé de musique du même auteur mis en français avec les éclaircissement nécessaires* (Paris: Charles Angot, 1668), pp. 101-127; see René Descartes, *Abrégé de musique suivi des Éclaircissement physiques sur la musique de Descartes du R.P. Nicolas Poisson*, traduction, introduction et notes par Pascal Dumont (Paris: Méridiens Klincksieck, 1990).

⁸⁹ Pietro Mengoli, *Speculationi di musica* (Bologna: Herede del Benacci, 1670); see Paolo Gozza, "A Mechanical Account of Hearing from the 'Galileian School': Pietro Mengoli's 'Speculationi di musica' of 1670," in *The Second Sense*, pp. 115-136.

⁹⁰ Daniello Bartoli, *Del suono de tremori armonici e dell'udito. Trattati* (Rome: per Nicolò Angelo Tinassi, 1679; 2nd ed., Bologna: P. Bottelli, 1680); see Paolo Gozza, "La musica nella filosofia naturale del Seicento in Italia," *Nuncius. Annali di Storia della Scienza* 1 (1986): 13-47, esp. 31-33.

⁹¹ Christensen, *Rameau*, pp. 209-251.

⁹² Jean Le Rond D'Alembert, *Elémens de musique théorique et pratique suivant les principes de M. Rameau, éclaircis, développés et simplifiés*. Nouvelle édition, revuë, corri-

stroyed: the venerable container of musical science is shattered and the parts of the treatise freed from their container start to live an independent life, generating new musical genres.

The musical treatise is not only theory, it is also the history of music. The “perfect knowledge of Music,” Zarlino says, “is acquired from two sources, one of which we will call *Historica* & the other *Methodica*.”⁹³ History and method are for Zarlino the sources of musical knowledge. They are not, however, independent genres but a different way of expressing the same principles: indirect and direct, via the comments of the ancients and the path of reason, or method. The distinction has to do with the ordering of materials in musical theory, a science rooted in the past which has always made history: from Boethius, who records the opinions of the Greek theorists, to Gaffurio and Zarlino, who recycle the whole of the tradition that precede them. Zarlino sets out the historical part of musical theory from the very frontispiece of his *Istitutioni harmoniche*: “in which, besides the material belonging to music, are mentioned many places of Poets, Historians & Philosophers, as can clearly be seen in reading them.”

The historical part of musical theory found its expression in a centuries-old rhetorical genre, encompassed within the systematic structure of the treatise: the praise of music. The Zarlinian variant of the *encomium musicae* extends from the Proem to the first eleven chapters of the First Part of *Le Istitutioni*, and forges a unitary and coherent theme: the comparison between ancient music and modern music (Proem); the origin of music and the certainty of the discipline (chapter 1); the praise of music through the *exempla* of its fabulous effects (chapter 2); the aim of music (chapter 3); the usefulness of music (chapter 4); the definition of music and its divisions (chapters 5 to 10); the distinction between speculative music and practical music, and between *musicus* and *singer* (chapter 11). *Le Istitutioni harmoniche* then deals with the methodical part of the musical edifice: the remaining chapters of the First Part, 12 to 44, set out the mathematical doctrines on which musical theory bases the manipulation of consonances; Part 2, in 51 chapters, describes the basic musical concepts: sounds, intervals, genres, modes, and so on, and brings to an end the speculative section. The practical section of *Le Istitutioni* also has two parts: Part 3, the 80 chapters on the art of counterpoint, and Part 4, the 36 chapters on the musical modes.

The musical treatise is therefore an articulated organism with multiple functions. It ideally encompasses the whole of the discipline: from the nar-

gée et considérablement augmentée (Lyon: J.-M. Bruyset, 1766); see Thomas Christensen, “Music Theory as Scientific Propaganda: The Case of d’Alembert’s *Elémens de Musique*,” *Journal of the History of Ideas* 50 (1989): 409-427.

⁹³ Gioseffo Zarlino, *Sopplimenti*, p. 10.

ration of its noble past and its present day 'renaissance' to the enunciation of its theoretical principles (*musica speculativa*) to their concrete application to compositional praxis (*musica practica*). It can therefore be read at different levels, by readers and scholars of different cultural extraction: music professionals interested in the solution of the concrete problems of their art, music theoreticians concerned with the systematic nature of musical concepts, mathematicians interested in applying numbers and geometrical figures to sonorous events, natural philosophers looking for the physical causes and psychological effects of sound, grammarians and scholars of rhetoric involved in investigating the rhythm and rhetorical clauses of the musical period.

Of the various divisions of the musical treatise, the historical part is the least specialistic, easily accessible to the reader not directly interested in the systematic sections. It traditionally precedes the other divisions of the treatise, fulfilling the role of musical protreptic, of an introduction exhorting to the study of music; and, given its vocation to communicate, it borrows from epideictic discourse the narrative style and thematic structure that can be easily memorized. The praise of music belongs to the genre of introductions to the liberal arts in Hellenistic and Roman culture inherited by Christian thought.⁹⁴ The Scholastic culture then sorts the *encomium musicae* into the taxonomic divisions responsible for the organization of matters in musical treatise writing. Preceding the modern musical protreptic is the 15th century dispute on the arts which redraws the epideictic parameters for singing the praise of arts in Humanistic civilization. From the 15th century the praise of music suddenly becomes vital: a petrified organism, transmitted without significant variants, is the most widespread and widely read musical genre of the Renaissance. Sensitive to the changes in culture and general public, the *encomium musicae* is a genre practised by humanists and men of letters in the academic prolusions and celebratory descriptions of performances by celebrated artists;⁹⁵ in the general introductions to mathematical writing designed to praise the *mathemata*, which regularly included music;⁹⁶ in the books of Renaissance magic, from Marsilio Ficino to Giovambattista Della Porta, written to point up the pneumatological theories on the power of music and to illustrate the physical

⁹⁴ See James Hutton, "Some English Poems in Praise of Music," *English Miscellany* 2 (1952): 1-63, also printed in James Hutton, *Essays on Renaissance Poetry*, ed. Rita Guerlac (Ithaca and London: Cornell University Press, 1980, pp. 17-73.

⁹⁵ See F. Alberto Gallo, "La musica in alcune prolusioni universitarie bolognesi del XV secolo," in *Sapere e/è potere*, 2:205-215, and his *Music in the castle: troubadours, books, and orators in Italian courts of the thirteenth, fourteenth, and fifteenth centuries* (Chicago and London: The University of Chicago Press, 1995).

⁹⁶ Gozza, "La musica tra matematica e antica teologia," in *Sapere e/è Potere*.

'effects' of sounds;⁹⁷ in the texts of the encyclopedic tradition, from Angelo Poliziano to Giorgio Valla to the encyclopedism of the 17th century;⁹⁸ and in certain Humanistic-pedagogic literature,⁹⁹ in the writings of the heurmatologists,¹⁰⁰ in Renaissance poetry.¹⁰¹

In time the encomium of music also experiments with its own metamorphosis and dissolution. Its classical topics desert their traditional rhetorical model and are contaminated by other cultural traditions, undermining historical narration and its epistemologic premises and generating new forms and traditions. The most extraordinary example is the topos of the *conditores* of the discipline, the Biblical and Pythagorean legend of the discovery of consonances. Transmitted by Boethius, who borrows it from Nicomachus and Aristides Quintilianus, passed on by later musical treatise writing until Zarlino, the legend had been visually encapsulated in the engraving of the *Theorica musice* by Gaffurio, taking root in the imagination of men of culture up to the 18th century. In the second half of the 18th century the ancient origin of musical theory was set aside and replaced by the modern origin of music, language, projected back into the past of human history by the nascent esthetical paradigm.¹⁰² But already long before its radical metamorphosis, the *encomium* had been reinterpreted by Vincenzo Galilei in the light of experience, "mother of all things." In his 1589 *Discorso* and the *Discorso particolare intorno alla diversita delle forme del diapason*,¹⁰³ Galilei is the first to discredit the mythical *conditores* of music, pointing up the mistake of Pythagoras and cracking one of the pillars of the musical tradition transmitted by the *encomium*: experience shows that the weights of the hammers in Gaffurio's plate are not defined by the relationships between simple whole numbers but by the relationships between numbers inverse to the square.¹⁰⁴ The crisis of the epistemological

⁹⁷ Walker, *Magic*; Gary Tomlinson, *Music in Renaissance Magic. Toward a Historiography of Others* (Chicago and London: The University of Chicago Press, 1993).

⁹⁸ Fiorella Brancacci, "L'enciclopedia umanistica e la musica: il 'Panepistemon' di Angelo Poliziano," in *La musica a Firenze al tempo di Lorenzo il Magnifico*, ed. Piero Garagiulo (Florence: Olschki, 1993), pp. 299-316.

⁹⁹ Palisca, *Humanism*, pp. 14-17, 100-106.

¹⁰⁰ Brian P. Copenhaver, "The Historiography of Discovery in the Renaissance: The Sources and Compositions of Polydore Vergil's 'De Inventoribus Rerum', I-III," *Journal of the Warburg and Courtauld Institutes* 41 (1978): 192-214, pp. 199-201.

¹⁰¹ See Hutton, "English Poems," John Hollander, *The Untuning of the Sky: Ideas of Music in English Poetry, 1500-1700* (Princeton, NJ: Princeton University Press, 1961); and Ludke Gretchen Finney, *Musical Backgrounds for English Literature: 1580-1650* (Westport, Conn.: Greenwood Press, 1976).

¹⁰² See Downing A. Thomas, *Music and the Origins of Language. Theories from the French Enlightenment* (Cambridge: Cambridge University Press, 1995).

¹⁰³ See Palisca, *Florentine Camerata*, pp. 180-197.

¹⁰⁴ See Claude V. Palisca, "Scientific Empiricism in Musical Thought," in *Seventeenth Century Science and the Arts* (Princeton, NJ: Princeton University Press, 1961), pp. 91-137, also printed in Palisca, *Studies*, pp. 200-235.

archetype of the praise of music thus gives rise to the modern experimental science of sound. Galilei's observation is confirmed by Marin Mersenne who reformulates the law of tensions, or the inverse of the square, in the first acoustic-mathematical law of the vibrating string;¹⁰⁵ Isaac Newton would on the other hand see in the legend of Pythagoras his own law of universal gravitation, deliberately concealed by the ancient sage in the "error" of the legend passed down by Boethius and later tradition.¹⁰⁶

In the course of the 18th century the musical treatise is shattered, and the different parts of the organism engender new forms. Even the topics of the *encomium musicae*, freed of their container, give birth to new genres: for example, the entry "Effets de la musique" in the *Encyclopédie*, drawn up by Rousseau, is based entirely on the *Tentamen de vi soni et musicae in corpus humanum* (1758) by Joseph-Luis Roger, the leading 18th century treatise of *musica iatrica*, a medical specialization of the topos of the extraordinary effects of ancient music.¹⁰⁷ But perhaps the most vivid legacy of the *encomium musicae* is the 18th century development of the historiographical genre: it is no coincidence that the first histories of music occur with the final separation of the two sources of musical knowledge included in the genre of the treatise, *historica* and *methodica*.¹⁰⁸

6 Nature and Art

In their *Mathematical Models of Musical Scales* Mark Lindley and Ronald Turner-Smith ground the theory of mathematical models of musical scales on two premises: first, *conventionalism*, the model should not be confused with the thing represented; second, *historicism*, the model should include pieces of the past: notation, "habits of musical thought," and so

¹⁰⁵ See Sigalia Dostrovsky, "Early Vibration Theory: Physics and Music in the Seventeenth Century," *Archive for History of Exact Sciences* 14 (1975): 185-187, and Peter Dear, *Mersenne and the Learning of the Schools* (Ithaca and London: Cornell University Press, 1988), pp. 158-159.

¹⁰⁶ See Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute/University of London, and Leiden: E.J. Brill, 1978), pp. 23-26, and Penelope Gouk, "The Harmonic Roots of Newtonian Science," in *Let Newton Be! A new Perspective on His Life and Works*, ed. John Fauvel, Raymon Flood, Michael Shortland, and Robin Wilson (Oxford: Oxford University Press, 1988), pp. 101-125.

¹⁰⁷ Cp. Joseph-Louis Roger, *Traité des effets de la musique sur le corps humain, traduit du latin et augmenté de notes par Etienne Sainte-Marie* (Paris: Brunot, 1803).

¹⁰⁸ See Warren D. Allen, *Philosophies of Music History. A study of general histories of music* (New York: Dover Publications, 1962), and Philippe Vendrix, *Aux origines d'une discipline historique. La musique et son histoire en France aux XVII et XVIII siècles* (Liège: Bibliothèque de la Faculté de Philosophie et Lettres, 1993).

on.¹⁰⁹ In fact the premise in their Introduction, “that mathematics can be treated as a matter of formal logic not inherently related to anything else,” makes it difficult, if not impossible, to understand musical models historically: for example, it makes “it easy to see what is wrong with ‘Pythagorean’ music theorists: they confuse a mathematical model of a thing with the thing itself.”¹¹⁰ According to the Authors, Vincenzo Galilei’s experiment of the weights applied to the strings undermined the authority of Pythagoras and destroyed the Pythagorean conception of music as ‘sounding number’.¹¹¹ Against the image of Vincenzo Galilei, mentor of Galileo and modern experimental science, the Authors depict the champion of Renaissance Pythagoreanism as an old fashioned ‘metaphysicist’: “The most eminent 16th century theorist, Gioseffo Zarlino ... adhered to the Pythagorean theory that music is “sounding number,” even in the face of Vincenzo [sic] Galilei’s neo-Aristoxenian attack.”¹¹² If singers without musical accompaniment did not sing just intervals, Zarlino had said, “the sounding number would be completely in vain and superfluous in Nature.” “It was a sad day for Pythagoreanism, the Authors comment, when its champion in the field of music theory was reduced to such an a priori argument.”¹¹³ The sad day for Pythagoreanism is, in fact, dictated by its original sin: confusing number with reality, the model with the thing represented.

Seeing things in the light of ‘conventionalism’ versus ‘metaphysics’ makes it impossible to understand historically the musical controversy between Zarlino and Vincenzo Galilei. The confusion between ideas and reality that Lindley and Turner-Smith accuse Zarlino of is unfair because “splendid Nature” (as he calls it) is for Zarlino the basis of his mathematical model of musical scale, the very possibility of music as science of ‘sounding number.’ And the criticism of Vincenzo does not have simply epistemological reasons but ‘practical’ ones too: in his *pars construens* he leans towards a recognition of music as art that Galilei perceives as compromised by the Zarlinian distinction of “natural” and “artificial”—it is better seen as part of the Renaissance debate on the contemplative and the active life rather than the argument between ‘constructionists’ and ‘deconstructionists’.

What do we sing today? Zarlino’s and Galilei’s question is not naive; it springs from the conviction that music is not the same throughout history, that modern music is different from ancient music. Whence the search for

¹⁰⁹ Mark Lindley and Ronald Turner-Smith, *Mathematical Models of Musical Scales. A New Approach* (Bonn: Verlag für systematische Musikwissenschaft, 1993), p. 12.

¹¹⁰ *Ibid.*, p. 11.

¹¹¹ *Ibid.*

¹¹² *Ibid.*, p. 232.

¹¹³ *Ibid.*, p. 232. On Lindley’s and Turner-Smith’s a-priori anti-‘Pythagoreanism,’ see, also, Knobloch, “Harmony and Cosmos,” pp. 55-56.

continuity, the desire to find in the culture of the Ancients some of the characters of the music of the Moderns. For some it is trying to find the principles of modern music in ancient science, for others it is trying to reduce “ancient music to modern practice.”¹¹⁴ Reducing ancient music to modern practice for Vincenzo Galilei means making modern music by capturing the expressiveness of ancient music, compromised by polyphony. Finding the principles of modern music in the science of the Ancients means for Zarlino deducing the rules of counterpoint from unchangeable mathematical-musical laws. In Galilei and Zarlino two ancient musical myths rediscovered by the Renaissance are at work: in Vincenzo, the humanistic myth of the ‘marvellous effects of ancient music’—music to be heard; in Gioseffo, the renaissance myth of ‘harmony’—music as perfect, absolute work.

What music do we sing today? Zarlino replies, “making no bones about it (as they say), that we sing [sang] the above-mentioned Natural species, or Ptolemy’s Diatonic Syntonon, and not the Ancient Diatonic or other species.”¹¹⁵ Galilei concedes to Zarlino that “what we sing today agrees more than any other Distribution with Ptolemy’s own Syntonon;”¹¹⁶ the controversial point for Vincenzo is the word “natural” and its opposite “artificial,” which Zarlino uses in relation to voices and instruments.¹¹⁷

Nature is the source of Zarlino’s musical theory. Zarlino borrows from the Peripatetic tradition the conception of the natural object as *poiesis*, nature as intrinsic principle of things (*natura naturans*). But Zarlino also takes on board another conception of nature, nature as object of the creating power of the divine mind (*natura naturata*): “Nature is the outcome of divine Art imposed on things, whereby they move towards their end.”¹¹⁸ In brief, Zarlino superimposes on the Aristotelian concept of *physis* as a poietic system the Platonic-Christian idea of the divine Demiurge, the geometer and architect God who orders natural reality on the basis of intelligible forms.¹¹⁹

The syncretism between Aristotelianism and Christian Platonism explains Zarlino’s remark that the music we sing today is “the Natural spe-

¹¹⁴ Nicola Vicentino, *L’Antica musica ridotta alla moderna pratica* (Rome: Antonio Barre, 1555; reprint ed. by Edward E. Lowinsky, Kassel: Bärenreiter, 1959).

¹¹⁵ Zarlino, *Sopplimenti*, p. 9.

¹¹⁶ Vincenzo Galilei, *Discorso intorno all’opere di messer Gioseffo Zarlino da Chioggia, et altri importanti particolari attenenti alla musica* (Florence: Giorgio Marescotti, 1589), pp. 124-125.

¹¹⁷ See Walker, *Studies*, pp. 14-26, and Cohen, *Quantifying Music*, pp. 79-85.

¹¹⁸ Zarlino, *Sopplimenti*, p. 20.

¹¹⁹ See Jürgen Mittelstrass, “Nature and Science in the Renaissance,” in *Metaphysics and Philosophy of Science in the Seventeenth and Eighteenth Centuries*. Essays in Honour of Gerd Buchdall, ed. Roger S. Woolhouse (Dordrecht/Boston/London: Kluwer, 1988), pp. 17-43.

cies or Diatonic Syntonon of Ptolemy.” The music that Zarlino has in mind is “vocal and natural melodies,” the sacred polyphonies without instrumental accompaniment, called ‘a cappella’. This music is “natural” because it is produced by the voice, a living unity of matter and form: the voice as matter of singing intones the “Forms” which “Mother Nature, Instrument of the great God,” has placed in our bodies so that the work of Creation is perfect. Every created thing possesses for Zarlino “its Form and its determined Figure” which in sonorous bodies is consonance, form “according to a certain and determined reason or proportion.”¹²⁰ The two postulates, that the universal forms of consonance exist in Nature and that “God and Nature never make anything in vain,” are to Zarlino the basis of knowledge and science.¹²¹ Ptolemy’s ‘diatonic syntonon’—*i.e.* the ‘right division of tone’—stands at the end of a complex scientific procedure based on the analogy between sound and extension, the pitch of the sound and the length of the string that generates it: “On a fully taut string, [divided] in two parts, the proportion found between one space and the other is the same as that to be found between one sound and the other.”¹²² Matter and form are separated, and sounds lose physical reality to acquire the status of ‘sounding numbers’: the ‘interval’ between the string and its half, $2/1$, is the mathematical form of the musical octave interval, the Greek diapason, “Mother and source of all Intervals;”¹²³ from this “Sounding whole divisible in parts” Zarlino mathematically deduces, and verifies through experience, that the “natural forms” of the consonances ordered in the scale of just intonation are defined by ratios between the first six integers, the *senarius*, the perfect number.¹²⁴

The continuity between nature and science paves the way for the continuity between nature and art. The musical universals in nature, exhibited by the *senarius* and ordered in the ‘syntonon’, are the building-blocks of music, the premises of the practical rules of counterpoint that the theorist offers up to the composer for musical creation. Artistic creation, the *opus perfectum*, is imitation of natural poesis; the art of the divine Demiurge hidden in Nature is the paradigm of human art which assumes Nature as its own ideal norm. Zarlino’s reply that the music we sing today is the “natural syntonon” affirms the affinity between Nature and Art, in its double meaning of science (theoretical music) and of composition and song (practical music): the perfection of music as the imitation of the divine creation of the world.

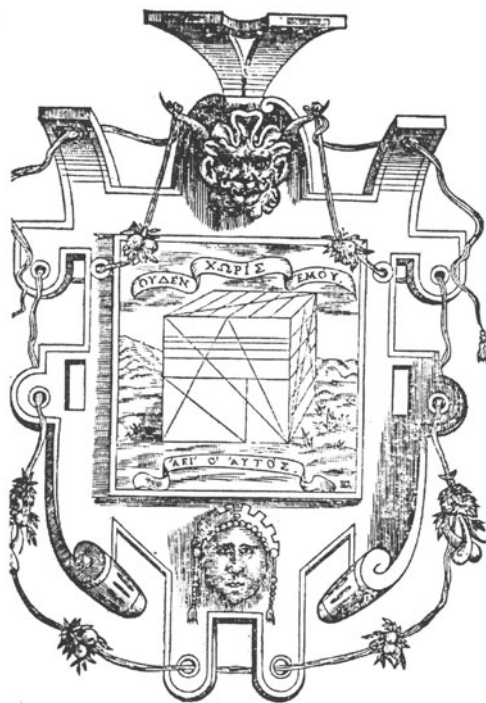
¹²⁰ Zarlino, *Sopplimenti*, p. 88.

¹²¹ *Ibid.*, p. 27.

¹²² Zarlino, *Dimostrazioni*, p. 147.

¹²³ Zarlino, *Sopplimenti*, p. 98.

¹²⁴ *Ibid.*, pp. 27-28.



6. Zarlino's emblem, from Giovanni Maria Artusi, *Impresa del molto R.M. Gioseffo Zarlino* (1604)

Zarlino's firm belief in harmony (Figure 6) is contrasted with the scepticism of Vincenzo Galilei, who upsets Zarlino's ordered synthesis. There is no single part of Zarlino's theoretical edifice that his "loving disciple" does not try to turn upside down. Gioseffo idealizes "stupendous Nature," in which he sees a system of forms that man tries to comprehend by reason and imitate by art; for Vincenzo Nature proceeds "without any cognition,"¹²⁵ and provides no laws or models to follow. Gioseffo believes that music is a science, for Vincenzo science worries pointlessly about numbers and figures to "regulate and proportionate" music which is sung. Zarlino's *senarius* is for Galilei merely one of the many "Zarlinish impertinent innovations,"¹²⁶ and the 'natural syntonon' is neither perfect nor natural: it has dissonant intervals on the various levels of scale, is instable, and, Galilei adds, is a product of art, which does not imitate nature but follows its own designs. For Zarlino the aim of nature and art is the perfect work, for Galilei music is communication ("the aim of Music is that it be heard,")¹²⁷ so that "the rules of the modern contrapuntists observed as inviolable

¹²⁵ Galilei, *Discorso*, p. 94.

¹²⁶ *Ibid.*, p. 98.

¹²⁷ *Ibid.*, pp. 116-117.

laws... will all be directly contrary to perfection.”¹²⁸ If at the end of this systematic demolition he is ready to concede “that what we sing today is more fitting to Ptolemy’s own Syntonon than to any other Distribution,” this does not mean that Galilei is a practical musician without any principles, a ‘grandchild of Rameau’: if Nature withdraws, the space is filled by Art, and the criterion of perfection gives ground to the demands of communication.

As regards the nature-art relationship, Vincenzo Galilei pays less heed to *physics* and more to the *ps*. Aristotelian *Quaestiones mechanicae*: nature follows the same course without deviating, human art changes constantly—it is projecting and making things that may or may not be, the origin of which lies in the person who actually produces. Nature and art, therefore, have different goals and in the pursuit of their own particular goals art is superior to nature. Characteristic professional pride leads Vincenzo at times to identify nature with matter, to which human art adds form from without: nature gives “the sound both of voices and of strings,” art gives “the form of the interval whether consonant or dissonant.”¹²⁹ The philosophical premise of this approach is the separation of the theory of the instrument from the theory of nature, of mechanics from *physis*: Galilei contrasts nature, minister of the natural motions of bodies, with mechanical art, the theory of instruments designed by man to pursue an end that is different from nature, or that nature cannot pursue.¹³⁰

The aim of art is expression—“to express with greater efficiency the ideas of the soul”—and communication—“to impress them secondarily with equal force in the minds of mortals.”¹³¹ Against Aristotle’s *Physics* or *Posterior Analytics* and the *Commentarius* of Proclus in *primum Euclidis Elementorum*, the mathematical texts close to Zarlino, Vincenzo juxtaposes the Eighth Book of *Politics*, the *Poetics*, the *Rhetoric* and the *Problemata*, the Aristotelian texts of the Florentine humanists and of the mentor of the Camerata dei Bardi, Girolamo Mei (1519-1594).¹³² In his letter to Vincenzo of 8 May 1572 Mei takes up the arguments in the *Problemata* on the human voice, distinguished from the voice of animals by “its meaningful speech:” the human voice brings to the animal cry, manifestation of pleasure and pain, articulated sounds capable of express-

¹²⁸ Vincenzo Galilei, *Dialogo della musica antica et della moderna* (Florence: Giorgio Marescotti, 1581; reprint ed. New York: Broude Brothers, 1968), p. 81.

¹²⁹ Galilei, *Discorso*, p. 79.

¹³⁰ *Ibid.*, pp. 73-74.

¹³¹ Vincenzo Galilei, *Dialogo*, p. 81.

¹³² See Claude V. Palisca, *Girolamo Mei (1519-1594): Letters on Ancient and Modern Music to Vincenzo Galilei and Giovanni Bardi*. Musicological Studies and Documents, 3 (Rome: American Institute of Musicology, 1960; 2nd, corrected edition, with Addenda, Rome: American Institute of Musicology, 1977).

ing the soul's motions and impressing them on the listener.¹³³ In his *Dialogo* Galilei takes up Mei's line of thought, and makes of it the premise to his antimodern musical argument in support of the expressiveness of ancient music.¹³⁴ In other words, music in Galilei and in Mei is discourse, not science of the necessary but art of the possible. It is music from the rhetorical and anthropological perspective of communication and fruition, in contrast to music from the perspective of the *opus perfectum et absolutum*.

The debate between Zarlino and Galilei is the turning point of the Renaissance. The 'nature' of Zarlino and the 'technics' of Galilei are the opposites of a synthesis bequeathed to posterity. Reconciling Gioseffo and Vincenzo, harmonizing nature and man, science and art, classical harmony and modern hearing: these are the themes music has to concern itself with in the next decades. How to reconcile arithmetic and poetry, number and word, Pythagoras and Orpheus?—this is Fabio Paolini. How to reconcile celestial and vocal motion, harmony of the spheres and musical composition, tracing *musica mundana, humana et instrumentalis* back to the same archetypes?—this is Kepler. How to reconcile reason and sense, geometry and musical hearing, mental order and sensible pleasure?—this is Descartes. How finally to reconcile Nature and mechanics, mathematical demonstrations and sensate experiences, while turning the sounding number into sound?—this is Galileo.

Paolini's synthesis belongs to the cabalistic, hermetic and neoplatonic tradition of Marsilio Ficino and Francesco Giorgi Veneto,¹³⁵ complicated with Zarlino, Francesco Patrizi and the Humanistic ideal of the expressiveness of music. The cathartic and religious function of music—the 'marvellous effects' of the song of Orpheus—lies for Paolini in the rationale of the number and in the rationale of the word, in arithmetic and rhetoric. As to number, Paolini in his *Hebdomades* draws on the Pythagorean distinction between *numeri numerantes* (ideal) and *numeri numerati* (material): the former archetypes of divine creation, the latter sensible copies in human creation.¹³⁶ As to words, Paolini draws on the syncretism between Plato and Aristotle in the dialogues *Della Poetica* of Francesco Patrizi:¹³⁷ Aristotelian theory of imitation and Platonic doctrine of the divine furor are assimilated in view of the common goal of poetry and music, cathartic and religious. Rhythm is what Paolini bases his arhythmo-poetic musical science on. The concept of rhythm embodies the double status of number,

¹³³ Ibid., pp. 89-117, esp. 113.

¹³⁴ Vincenzo Galilei, *Dialogo*, pp. 79-89, esp. 89.

¹³⁵ See Walker, *Magic*, pp. 126ff., and Cesare Vasoli, *Profezia e ragione. Studi sulla cultura del Cinquecento e del Seicento* (Naples: Morano, 1974), pp. 129-403.

¹³⁶ Paolini, *Hebdomades*, pp. 231-237.

¹³⁷ Francesco Patrizi, *Della Poetica* (Ferrara: V. Baldini, 1586), ed. Daniello Aguzzi Barbagli, 3 vols. (Florence: Istituto Nazionale di Studi sul Rinascimento, 1969-1971); see Palisca, *Humanism*, pp. 402-405.

ideal and material. Ideal rhythm is the vocal kind, found in the metre of poetical verse, ideal because it is vehicle of rational meaning. Material rhythm on the other hand is instrumental, intrinsic to music without poetry, material because it does not transmit rational meanings. Between Aristotle and Plato, Paolini places Saint Augustine's *De musica* revisited by Salinas. Placing music in an intermediate position between mathematics and poetry-rhetoric finds a parallel in the idea of musical composition laid out in the *Hebdomades*, the monodic song accompanied by simple instrumental harmonies: a model similar to that of the Camerata Fiorentina and the Academie de poesie et de musique of Jacques Mauduit and Antoine Baif.¹³⁸

The sophisticated synthesis of Fabio Paolini is 'the swansong' of the Florentine and Venetian, Italian musical Renaissance. Paolini's ideal numbers still live in the motionless and archaic cosmos of Robert Fludd, at a time when the struggle among the symbols of the divine has already given way to geometrical images, closer to God and the moving, musical cosmos of modern astronomy.

Reconceiving Music

7 *Harmony*

If there were stillness and no movement, there would be silence: and if there were silence and if nothing moved, nothing would be heard. Then if anything is going to be heard, impact and movement must first occur.¹³⁹

The incipit of the Preface to Euclid's *Sectio canonis* identifies sound and motion: a motionless cosmos is a silent cosmos, where nothing is heard, a moving cosmos is a sounding cosmos, alive. To the spatialized sound of Pythagorean cosmology, metaphor for a world at rest, the Euclidean text contrasts temporalized sound, a metaphor for a world in motion animated by sonorous events.¹⁴⁰ The identification of sound and motion in an ancient writing on music rediscovered in the Renaissance¹⁴¹ and attributed to

¹³⁸ Paolini, *Hebdomades*, pp. 149-164; see Daniel P. Walker and François Lesure, "Claude Le Jeune and 'musique mesurée'," *Musica Disciplina* 3 (1949): 151-170.

¹³⁹ "The Euclidean *Sectio Canonis*," in *Greek Musical Writings II. Harmonic and Acoustic Theory*, ed. Andrew Barker, (Cambridge: Cambridge University Press, 1989), p. 191.

¹⁴⁰ See Alan C. Bowen, "Euclid's *Sectio Canonis* and the History of Pythagoreanism," in *Science and Philosophy in Classical Greece*, ed. Alan C. Bowen (New York and London: Garland Publishing, 1991), pp. 164-187.

¹⁴¹ The *Sectio canonis* was first translated into Latin by Giorgio Valla (Venice: Simone Bevilacqua, 1497), then by Johannes Pena (Paris: Andreas Wechel, 1557) and Conradus

Euclid helped determine a new disciplinary statute to musical science. The object of music was still quantity it had in common with the other mathematical disciplines: besides music, arithmetic, geometry and astronomy. But the quantity music dealt with was continuous quantity, not discrete quantity of the traditional quadrivial system. Continuous quantity refers to the geometric magnitudes generated, as indicated by the term 'continuous', by motion: ideal motion of the point on the plane (geometry), material motion both of celestial bodies in cosmic space (astronomy) and of sounds in musical space (music). Discrete quantity refers on the other hand to arithmetical magnitudes, numbers (arithmetic). The analogy between sound and motion took music away from arithmetic, to which it was subordinate, and moved it nearer to astronomy, sister discipline of music since Plato's *Republic*. This repositioning of music determined the new alliance between 'polyphonic revolution' and 'astronomic revolution', both of which from Copernicus to Newton took place under the guise of a reformed Pythagoreanism.

In music the 'reformed Pythagoreanism' was the Zarlinian *senarius*. When in 1540 the natural philosophical community was informed of the Copernican undertaking by Rheticus's celebrated *Narratio prima* (1540), the clear reference to the ancient heliocentric hypothesis attributed to the Pythagoreans was flanked by geometrical, musical and numerological analogies which conferred on the cosmos of Copernicus a harmony that was missing in the ancient astronomers.¹⁴² In calculating the harmony of planetary movements, Rheticus writes, the ancient astronomers should have imitated musicians when they tune their instruments to obtain a perfectly consonant harmony; with Copernicus planetary motion conforms, on the other hand, to a mathematical principle regulated by the arrangement of the planets and their yearly orbits around the Sun, in the same way that the sounds of different musical strings conform to that of a single tuned string.¹⁴³ The Philolaic-Copernican cosmos is in Rheticus' text a dynamic musical cosmos, animated by the Sun, "both choral dancer and choral leader," the heliocentric variant of the Plotinian picture of the cosmos as dancer, taken up by Ficino.¹⁴⁴ And with regard to the number and arrangement of celestial bodies, "who could have chosen a more suitable and more appropriate number than six? By what number could anyone more

Dasypodius (Strausburg: Christian Mylius, 1570); see Gallo, "Die Kenntnis," pp. 16-17, and Palisca, *Humanism*, pp. 67ff.

¹⁴² Georg Jachim Rheticus, "De libris revolutionum Nicolai Copernici *Narratio prima*," in *Three Copernican Treatises: The Commentariolus of Copernicus, the Letter against Werner, the Narratio prima of Rheticus*, translated with introduction and notes by Edward Rosen (New York: Columbia University Press, 1939).

¹⁴³ *Ibid.*, pp. 138-139.

¹⁴⁴ Marsilio Ficino, *Opera, & quae hactenus extitère, & quae in lucem nunc primum prodire omnia*, 2 vols. (Basle: ex off. Henricpetrina, 1576), 2:1746.

easily have persuaded mankind that the whole universe was divided into spheres by God the Author and Creator of the world?... Moreover, the celestial harmony is achieved by the six afore-mentioned movable spheres. For they are all so arranged that no immense interval is left between one and another; and each, geometrically defined, so maintains its position that if you should try to move any one at all from its place, you would thereby disrupt the entire system.”¹⁴⁵ When in the Preface to his *De revolutionibus orbium coelestium* (1543), Copernicus reproached astronomers with having lost sight of “the main thing, the shape of the world and the symmetry of its parts,” he could not better indicate the theme of the harmony of a universe created by ‘God the perfect geometrician’ of the Pythagorean and Platonic musical tradition. Chapter 10 of *De revolutionibus*, “The order of the heavenly spheres,” underlines the superior perfection of the new astronomical system, the only one able to achieve the true harmony of the world that God the geometrician had created with “admirable symmetry” of the parts and “the precise harmonic relation between motion and size of the spheres.”¹⁴⁶

Unlike Copernicus, Johannes Kepler did not limit himself to showing the order and symmetry of the solar system, he wanted to discover the archetypal laws that govern it. These laws are mathematical, more precisely geometrical. Geometrical truths are co-eternal with God and exist as copies in physical reality where the human mind, an image of the Creator, recognizes them.¹⁴⁷ The primacy of geometry is in step with the demolition of the ‘sounding number’ argued by Kepler. Rheticus is wrong when in his *Narratio prima* he deduces the number of the six moving skies from the sacrality of the *senarius*: according to Kepler, whoever talks of cosmology should not base his reasoning on numbers, which “have obtained dignity from things that came after the Creation.”¹⁴⁸ In astronomy Kepler tries to determine the number and the distances of the planets from the five regular polyhedra of the Platonic tradition; in music Kepler traces the origin of consonances to the regular polygons inscribed in the circle. The key to understanding the primacy of geometry in Kepler is the *Commentarii* to

¹⁴⁵ Rāthicus, “Narratio prima,” pp. 144-147.

¹⁴⁶ Nicholas Copernicus, *On the Revolutions*, edited by Jerzy Dobrzycki, translation and commentary by Edward Rosen (London: The Macmillan Press, and Cracow: Polish Scientific Publishers, 1978), pp. 18-22, esp. 22; see Robert S. Westman, “Proof, Poetics, and Patronage: Copernicus’ Preface to *De revolutionibus*,” in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert S. Westman (Cambridge: Cambridge University Press, 1990), pp. 168-205.

¹⁴⁷ See Walker, *Studies*, pp. 34-62.

¹⁴⁸ Johannes Kepler, *Mysterium Cosmographicum, editio altera* (1619), in Johannes Kepler, *Gesammelte Werke*, ed. Max Caspar et al. (Munich: C.H. Beckische Verlag, 1938-), 8:24.

Euclid by Proclus.¹⁴⁹ Proclus identifies perfect geometrical images with divine archetypes and with the mathematical nature of the *anima mundi*, and in Book 4 of his *Harmonice mundi* Kepler cites Proclus, translating word for word the long passage on the cosmogonic myth of Plato's *Ti-maeus*, the other source of Kepler's cosmology.¹⁵⁰

Of the five *Harmonices mundi* Books, the third on harmonics occupies the central position, between the two geometrical Books and the two natural ones. (Figure 7) The original scheme foresaw a different lay-out. Once the consonances ("harmonicis rationes") had been deduced from the regular polygons inscribed into the circle, it was a question of introducing them into the world in the other three books, the first of which attributed harmonies to God the Creator of the heavens, the second to Nature, the minister of motion, and the third to Man, maker of the voice generated by motion: "Harmonicis rationes hactenus descriptas in Mundum introduceremus tribus libris alijs, quorum primus Deo coelorum Conditori, secundus Naturae motuum variorum administratae, tertius Homini, vocis, quae ex motu gignitur, compoti, tribueret Harmonias."¹⁵¹ Kepler not only inverts the order, "initio ab humano cantu facto, transituri inde ad Naturae opera, et sic demum ad Opus Creationis" ("we started from the songs of man, we will then pass on to the works of Nature, and finally to the Work of Creation;") he also, as early as in the Third Book, conjugates the archetypes of consonance with the concrete harmonies of singing: "sed etiam finem speculationis abstractae cum principio concretarum Harmoniarum in Cantu, coniungeremus eodem libro tertio."¹⁵² Book 3 on harmonics is therefore a musical treatise modelled on the *dispositio* of Renaissance musical treatises: to the theoretical part, *musica speculativa*, on the deduction of consonances from the regular polygons inscribed in a circle, Kepler adds a practical part, *musica activa*, devoted to song. Kepler places music at the centre of the book that God has waited six thousand years for: the music of man stands at the threshold to the world, the motions of the human voice are the *introitus* to the sonorities of heavenly motion, to the *musica intelligibilis* centred around the "Sol auditor et choragus." How can we explain the extraordinary position of music in Kepler's cosmology?

¹⁴⁹ Francesco Barozzi, *Procli Diadochi... in primum Euclidis Elementorum librum Commentariorum ad universam mathematicam disciplinam tradentium libri IIII* (Padua: exc. Gratosus Perchacinus, 1560); see Proclus, *A Commentary on the First Book of Euclid's Element*, translated with Introduction and Notes by Glenn R. Morrow (Princeton, NJ: Princeton University Press, 1970).

¹⁵⁰ Johannes Kepler, *Harmonice mundi*, in Kepler, *Werke*, 6:218-221; see Proclus, *Commentary*, pp. 10-15.

¹⁵¹ *Ibid.*, 6:93.

¹⁵² *Ibid.*

Ioannis Keppleri
HARMONICES
M V N D I

LIBRI V. QVORVM

Primus GEOMETRICVS, De Figurarum Regularium, quæ Proportiones Harmonicas constituunt, ortu & demonstrationibus.

Secundus ARCHITECTONICVS, seu ex GEOMETRIA FIGVRATA, De Figurarum Regularium Congruentia in plano vel solido:

Tertius propriè HARMONICVS, De Proportionum Harmonicarum ortu ex Figuris; deque Naturâ & Differentiis rerum ad cantum pertinentium, contra Veteres:

Quartus METAPHYSICVS, **PSYCHOLOGICVS** & **ASTROLOGICVS**, De Harmoniarum mentali Essentiâ earumque generibus in Mundo; præsertim de Harmonia radiorum, ex corporibus cœlestibus in Terram descendentibus, eiusque effectû in Natura seu Anima sublunari & Humana:

Quintus ASTRONOMICVS & **METAPHYSICVS**, De Harmoniis absolutissimis motuum cœlestium, ortuque Eccentricitatum ex proportionibus Harmonicis.

Appendix habet comparationem huius Operis cum Harmonices Cl. Ptolemæi libro III. cumque Roberti de Fluctibus, dicti Flud. Medici Oxoniensis speculationibus Harmonicis, operi de Macrocosmo & Microcosmo insertis.



Cum S.C. M^{ta}. Privilegio ad annos XV.

Lincii Austriæ,
Sumptibus GODOFREDI TAMPACHII Bibl. Francof.
Excudebat IOANNES PLANCVS.

ANNO M. DC. XIX.

How does music mediate geometry and the world? The theme running through the *Harmonice mundi* is harmony, the passage from static geometrical archetypes to harmonic proportions, the so-called ‘laws of motion’: “à un monde en repos,” as Koyré says, it contrasts a world in motion, animated and harmonic. Kepler perceives musical sounds not as numbers, simple collections of individuals, but as highly organized movements of voices through time, carried out by a musical practice that is the extraordinary revolution of the Moderns, a prelude to the astronomic discoveries themselves. In his *Harmonices mundi libri V* Kepler finds the perfect consonances in the properties of geometrical figures: the circle and the line (*musica theorica*: Book 3, chapters 1 to 5;) he then discovers these archetypal harmonies in the motions of voices (*musica practica*, “Hominis seu Artis opus:” Book 3, chapters 6 to 16,) in the motions of nature (*musica astrologica*, “Naturae opus:” astrological Book 4) and in planetary motion (*musica mundana*, “opus denique Dei Creatoris:” astronomic Book 5.) It is the variant of the tripartite harmony of the Pythagorean and Boethian musical tradition: a science which contaminates geometry, music and astronomy along the lines of the cosmogonic tradition of Plato’s *Timaeus* and his Neoplatonic commentaries, and which Kepler calls “mathesis-physica”¹⁵³—an expression also used by Isaac Beeckman to define a context characterized by scientific-musical interests common to the young Descartes, and that Mersenne relates to his own mechanical musical science within the framework of Augustinian *harmonie universelle*.¹⁵⁴

The concept of harmony as measure of the motion of voices through time, effected by polyphony, offers a glimpse of the “terms,” not visible at the time of the *Mysterium Cosmographicum*, of the harmonic proportions of celestial movements:

if therefore we are looking for Harmonies, let us look for them not in these intervals, as semidiameters of Orbits, but in those intervals, as measurements of motion, *i.e.* in the movements themselves.¹⁵⁵

Modern harmony stands thus as “the genuine archetype of cosmic work.” In his attempt to reach the place where the secret harmony of the world has been hidden away for thousands of years, Kepler invites musicians to rise with him. It is through the ears of modern musicians that Nature manifested itself, just as it is, to the Mind of man:

¹⁵³ Ibid., p. 100: “... Mathematices Physicesque partem (*sc.* musicam)...”

¹⁵⁴ See Dear, *Mersenne*, pp. 76-77, 168-169.

¹⁵⁵ Kepler, *Harmonice mundi*, in *Werke*, 6:310: “Ergò si quaerimus Harmonias, quaeramus eas non in his intervallis, ut sunt semidiametri Orbium; sed in illis, ut sunt mensurae motuum, hoc est, in ipsis potiùs motibus.”

Follow me, modern musicians, and express your opinion on this matter by means of your arts, unknown to antiquity; Nature, always generous with her gifts, has at last, having carried you two thousand years in her womb, brought you forth in these last two centuries, you, the first true likenesses of the universe; by your symphonies of various voices, and whispering through your ears, she has revealed her very self, as she exists in her deepest recesses, to the Mind of man, the most beloved daughter of God the Creator.¹⁵⁶

The relationship between geometric symbols and musical and astro-nomic reality places Kepler's *Harmonice mundi* in an original position in the centuries-old *musica mundana*, as witness the controversy which on the publication of his book pitted Kepler against Robert Fludd (1547-1637). In the Appendix to Book 5 Kepler discussed the first two parts of the *Utriusque cosmi... historia* (1617-1618) by Robert Fludd. Fludd was interested in the analogy between macrocosm and microcosm, between man and the world, a relationship he examined through musical analogy: the cosmos is a musical instrument, a monochord extending from the highest to the lowest level of creation, from the angelic choirs to the dumb earth. (Figure 2)

The monochord ranges the extension of two octaves, on which the three worlds—elemental, ethereal and angelical—are hierarchically placed. On high the hand of God tunes this *fides mundana* (string of the world). The string of the instrument is divided into 15 musical notes, from bottom G to to middle G, on the sphere of the Sun, to upper G, and includes two octaves (*disdiapason*): material octave, from the Earth to the Sun, and formal octave, from the Sun to the top of the *monochordum mundi*, consisting in form without matter. The two octaves are divided into Pythagorean intervals: fifth (*diapente*) and fourth (*diatessaron*), expressed on the left side by the ratios $\frac{3}{2}$ (*proportio sesquialtera*) and $\frac{4}{3}$ (*proportio sesquitercia*). The material fourth consists in four elements, earth, water, air and fire, and its reflected image is the formal fourth, comprising the angelic region, from the sphere of the fixed stars to the last of the three angelic orders. The region from the fixed stars to the sphere of the Sun coincides with the extension of a formal fifth, symmetrical to the material fifth, the distance of the Sun from the Moon (note the error in the figure: the arc of the *diapente materialis* and the corresponding one of the *proportio sesquialtera* should

¹⁵⁶ Kepler, *Werke*, 6:323 (trans. Walker, *Studies*, p. 39:) "Sequimini Musici moderni, remque vestris artibus, antiquitatis non cognitis, censete: vos his saeculis ultimis, prima universitatis exempla genuina, bis millium annorum incubatu, tandem produxit sui numquam non prodiga Natura: vestris illa vocum variarum concentibus, perque vestras aures, sese ipsam, qualis existat penitissimo sinu, Menti humanae, Dei Creatoris filiae dilectissimae insussurravit."

end in C). The symmetry of the diagram of the world is perfect.¹⁵⁷

Kepler does not comment on Fludd's system, he criticizes him for basing harmony on abstract numbers (*numeri numerantes*).¹⁵⁸ For Kepler numbers have no demonstrative force; they derive from measurement (*numeri numerati*), hence presuppose homogeneous objects, having the same unit of measure. Fludd's harmonies are based on the numerical similarity of incommensurable objects, such as musical intervals and the regions of the cosmos; Kepler's on the other hand are derived from the ratios between the minimum and maximum angular velocities of the planets seen from the Sun. Fludd defends the idea of numerical symbols: without the mystery of occult abstract numbers it is not possible to grasp the intimate nature of things, or the relationship between natural and supernatural things. In brief, a Platonic God intent on geometrizing is the basis for Kepler's and Fludd's cosmology. The difference lies in the fact that Kepler's analogies are ratios between homogeneous quantities that correspond to measurable properties of the physical universe, while those of Fludd are numerical analogies between non homogeneous quantities, outside observed reality. Alongside this basic divergence, there are other substantial differences between the celestial harmonies of Fludd and Kepler. Fludd's harmonies are based on the scales in the traditional Pythagorean-Boethian system of intonation, and presuppose the centrality of the Earth. Kepler's celestial harmonies, on the other hand, are polyphonic, hence in just intonation, as they accept thirds and sixths, and are centered on the Sun.¹⁵⁹ The polyphonic revolution thus came to shape both *musica mundana* and modern astronomy, culmination of the centuries-old relationship between the two "sister disciplines" of Plato's *Republic*.

The 'Pythagorean' or 'Platonic' dream of the protagonists in the 'astronomic revolution,' from Copernicus to Kepler to Galileo, was eventually fulfilled by Isaac Newton (1642-1727). Book 3 of his *Philosophiae naturalis principia mathematica* (1687), "De Mundi Systemate," distills in one simple mathematical law, the law of universal gravitation, all previous astronomic observations. After expounding Kepler's three laws, Newton reinterprets them dynamically in the light of the law of universal gravitation. In the subsequent propositions, 4 to 9, the inverse square law is gradually extended to cover all bodies of the solar system and the physical universe. Newton then backs up the propositions 6 to 9, which expound the core of

¹⁵⁷ See Peter Amman, "The Musical Theory and Philosophy of Robert Fludd," *Journal of the Warburg and Courtauld Institutes* 30 (1967): 198-227.

¹⁵⁸ Kepler, *Werke*, 6:374-375; see Judith V. Field, "Kepler's rejection of numerology," in *Occult and Scientific Mentalities in the Renaissance*, ed. Brian Vickers (Cambridge: Cambridge University Press, 1984), pp. 273-296. See, also, Robert S. Westman, "Nature, art, and psyche: Jung, Pauli, and the Kepler-Fludd polemic," in *Occult and Scientific Mentalities*, pp. 177-229.

¹⁵⁹ See Walker, *Studies*, p. 34.

gravitational theory, with numerous proofs from the ancient philosophers.¹⁶⁰ If Copernicus, Kepler and Galilei had sought in the wisdom of the Ancients the sign of a venerable astronomic, harmonic and heliocentric truth to contrast the geostatic model of Aristotle and Ptolemy, Newton now incorporates the proofs of the Ancients in his own mathematical astronomy. And just as Copernicus and the 'Copernicans' had often understood progress in astronomy as a regression towards propositions intuited by the Ancients, so Newton now considers his own heliocentric and vacuist system as an experimental and mathematical retrieval of an ancient truth till then hidden. In the Scholium to Proposition 8, on the law of the inverse of squares, Newton 'reads' in the ancient Pythagorean concept of the harmony of spheres his own theory of universal gravitation expressed in symbolic form.¹⁶¹ By comparing the weights that stretch the strings with the weights (mass) of the planets, and the lengths of the strings with the distances of the planets (*musica mundana*), Pythagoras discovered that the masses of the planets towards the Sun are like the squares of their distances. Pythagoras then obfuscated the law of the cosmos by expressing the musical ratios with simple numbers, something which gives a correct result for the length of the strings but not for the weights. The fables of Apollo, Pan and Orpheus, and the legend of Pythagoras weighing the hammers, provided the key to interpreting authentic celestial harmony which only the initiated like Newton were able to penetrate.

The interpretation of the harmony of spheres is the apex of the theoretical-musical learning that Newton had already applied both to optics and the theory of colours and to his historical and theological studies.¹⁶² Newton's considerations in the last two Scholia of Book 3 of the *Principia* on the writings of Macrobius and the Orphic fragments point to the close tie between the musical ratios underlying the inverse square law and the Newtonian image of God: a God highly expert in mechanics and geometry, along the lines of the Pythagorean-Platonic tradition of "God who eternally geometrizes."

8 *Hearing*

The object of music is sound, its purpose to give pleasure and arouse in us various

¹⁶⁰ See Paolo Casini, "Newton: The Classical Scholia," *History of Science* 22 (1984): 1-58.

¹⁶¹ Ibid., pp. 24-38; see, also, James Edward McGuire and Piyo Rattansi, "Newton and the 'Pipes of Pan'," *Notes and Records of the Royal Society of London* 21 (1966): 108-143.

¹⁶² Penelope Gouk, "The Harmonic Roots of Newtonian Science," in *Let Newton Be!*, pp. 101-125.

passions.¹⁶³

The incipit to the *Compendium musicae* (first draft 1618 / first ed. 1650) (Figure 8) by René Descartes (1596-1650) sets music, in true Aristotelian fashion, among the objects of hearing: sound, the object of musical theory, encounters the listener who draws pleasure and passions from the music. Pleasure and passions are possible provided the sound is musical—in terms of the Pythagorean paradigm taken up by Descartes, the sound must have a mathematical structure purified by occult timbre qualities that cannot be quantified:

In view of the aim [*i.e.*, to give pleasure and arouse various passions] the means of music are basically two properties of sound: the ratios of duration or tempo, and of pitch in relation to acuteness and loudness. Let the natural philosophers study the quality of sound, *i.e.* from which body sound is produced and under which conditions it may be most pleasing.¹⁶⁴

In the light of these premises Heinrich Bessler's comment, "that in the history of musical theory Descartes is the first to move not directly from the music but from the listener," is only partially true.¹⁶⁵ The Zarlinian paradigm in the *Compendium musicae* structures hearing as a perception of the mathematical ratios immanent to music; only later, in the mature Descartes, does Cartesian hearing free itself from the mathematical ontology of musical theory, and become 'modern'. The two Descartes vis-a-vis, the young mathematician of the *Compendium* and the mature philosopher of the *Traité de l'homme* and the *Passions de l'âme*, define a context for musical hearing in the early 17th century that stretches from the 'aesthetic' to the 'pathetic', from pleasure through perceiving ratios to moving the passions of the soul. The context is the *musica humana* of Boethius, the mind-body relationship as conceptual structure of the emotional power of music: a metaphysical rather than rhetorical context, a long way from the *Affektenlehre* which dominates musical historiography.

¹⁶³ René Descartes, *Musicae Compendium* (Utrecht: typis Gisberti à Zjil & Theodori ab Ackersdjick, 1650), in René Descartes, *Oeuvres*, ed. Charles Adam and Paul Tannery. Nouvelle Présentation, 13 vols. (Paris: J. Vrin/CNRS, 1964-1974), 10:89 1-5: "Huius [*sc.* musicae] obiectum est sonus. Finis, vt delectet, variosque in nobis moveat affectus."

¹⁶⁴ *Ibid.*, 9-13: "Media ad finem, vel soni affectiones duae sunt praecipuae: nempe huius differentiae, in ratione durationis vel temporis, & in ratione intensionis circa acutum aut grave. Nam de ipsius soni qualitate, ex quo corpore & quo pacto gratior exeat, agant Physici."

¹⁶⁵ Heinrich Bessler, *Das musikalische Hören der Neuzeit* (Berlin: Akademie-Verlag, 1959), p. 30.

R E N A T I
 D E S - C A R T E S
 M V S I C Æ
 C O M P E N D I V M.



AMSTELÆDAMI,
 Ex Typographia BLAVIANA, MDC LXXXIII.
Sumptibus Societatis.

8. Title page of René Descartes's *Compendium musicae* (1683)

The “premises” (*praenotanda*) of the *Compendium*, the first of which “All senses are capable of some pleasure” represents, according to Bessler, “the new point of view of pleasure present in the soul,”¹⁶⁶ show how the origin of Cartesian pleasure is in fact the Aristotelian doctrine of the affinity between sense and the object of sense with proportion: if sound, the object of hearing, is a consonance and hence a proportion, the

¹⁶⁶ Ibid.

sense of hearing too must be a proportion.¹⁶⁷ That hearing is inscribed in the mathematical-musical, Zarlinian, paradigm can equally be deduced from what is ‘missing’ in the *Compendium*. Descartes does not say how sound is propagated and how it is perceived by the ear; he does not describe the physiology of hearing, hence the Cartesian ear is mental, not physical; furthermore, the model of auditory perception is not so much hearing as vision, and the geometric examples Descartes sets forth in his *praenotanda* are visual not auditory.¹⁶⁸ Since the *Compendium* does not address the physics of sound and the physiology of hearing, the passions of the soul—the other end of music besides pleasure—are also lacking. In all of this the young Descartes displays a scant propensity towards the Aristotelian themes of auditory perception. For Aristotle, hearing is essentially activity, the sound is transported by the movement of air and the ear is a box full of air—undispersed air, because it is enclosed and its reception of sounds is accurate.¹⁶⁹ In Descartes’ *Compendium musicae*, however, there is number not sound, and the aesthetic pleasure of the *sounding numbers* sidelines the pathetic effect, limited to the brief mention of the traditional analogies major mode-glad and minor mode-sad, quick rhythms=vital passions (joy, and so on) and slow rhythms=restless passions (languor, sadness, fear, pride...)¹⁷⁰ The incipit to the *Compendium* “the aim of music is to give pleasure and arouse various passions” finds then only half an answer—*ut delectet*, to give pleasure. We have to take seriously the passage in the *Compendium* where Descartes claims that a close examination of the music-passions relationship depends on a good understanding of the motions of the soul, “de quibus nihil plura,” “on which [I will say] no more.”¹⁷¹

After the *Compendium* comes the discovery of the body, and the discovery of reality determines dualism and conflict. Dualism means that mind and body are different worlds—that there is no similarity between the vibrations of the sounding bodies outside of us and the motions of the soul inside us which we call passions. Nonetheless, *la maladie de l’âme* is the symptom of its bodily tie, and the passions bear witness to this bond between the mind and its body which only death can undo.

In the *Traité de l’homme* (first draft 1632, first Latin ed. 1662) dualism is the diversity between sonorous sensation and its representation. The mechanistic physiology of the treatise describes the material process through which the vibrations of the air become sounds in the soul. The fi-

¹⁶⁷ Aristotle, *De anima*, III, 2, 426a 28 - 426b 8.

¹⁶⁸ See my “Descartes” in this Collection.

¹⁶⁹ See Alan Towey, “Aristotle and Alexander on Hearing and Instantaneous Change: A Dilemma in Aristotle’s Account of Hearing,” in *The Second Sense*, pp. 7-18, esp. 16.

¹⁷⁰ Descartes, *Oeuvres*, 10:95 10-15.

¹⁷¹ *Ibid.*, 22-23.

bres that make up the nerves are attached at the periphery to the senses and at the center to a carillon—the brain where the soul is housed. The fibres of the acoustic nerve in the internal cavity of the ear can be easily stimulated by air vibrations from outside which strike the ear drum. Via the nerves the vibrations reach the carillon and stimulate the brain, a soft and elastic matter which predisposes the mind to the idea of sound. The idea conceived in the mind is different from the bodily sensation: the latter is a particular motion of the spirits in certain parts of the brain, the former is a geometrical image similar to those in the *Compendium* on the calculus of consonances.¹⁷² There are as yet still no passions, no conflict. The sonorous vibrations travel straight to the brain without passing through the heart, and the furnace of the machine is not led to overheat the blood producing large quantities of vapours which in the cerebral cavity act on the soul, eliciting passions. If hearing is to be ‘pathetic’ the brain is not enough, the heart is also needed—the nervous function must be merged with the vital function, by the animal heat generated by the motion of blood. At the apex of this machine, the soul thus endures the action of bodies through the organ which binds it to the body, through the gland suspended in the brain cavity which, like a bell, is sensitive to the slightest tremor of the spirits and receives contrary impulses.¹⁷³ Precisely

...it is only in the repugnance which exists between the movements which the body by its animal spirits, and the soul by its will, tend to excite in the gland at the same time, that all the strife which we are in the habit of conceiving to exist between the inferior part of the soul, which we call the sensuous, and the superior which is rational, or as we may say, between the natural appetites and the will, consists.¹⁷⁴

Here then is the fiat of the passions, of the conflicts mankind imagines between the superior and inferior parts of the soul—different pressures, contrary motions of the gland excited at one and the same time by the will and by animal spirits: by the spirits that pull on the gland, tilting the soul to one side, by the soul, that tilts the movement of the gland in the opposite direction.

¹⁷² Descartes, *Traité de l'homme*, in *Oeuvres*, 11:150; see Kassler, *Inner Music*, pp. 43-48.

¹⁷³ Descartes, *Passions de l'âme*, in *Oeuvres*, 11:337 (art. 12.)

¹⁷⁴ *Ibid.*, art. 47, p. 364: "...en la repugnance, qui est entre les mouvements que le corps par ses esprits, & l'ame par sa volonté, tendent à exciter en mesme temps dans la glande, [que] consistent tous les combats qu'on a coustume d'imaginer entre la partie inferieure de l'ame, qu'on nomme sensitive, & la superieure qui est raisonnable, ou bien entre les appetites naturels & la volonté." See Descartes, *The Philosophical Works*, trans. Elizabeth S. Haldane and G.R.T. Ross, 2 vols. (Cambridge: Cambridge University Press, 1979), 1:352-353.

Between the *Traité de l'homme* and the *Passions de l'âme* (first draft 1645-46) comes the episode of "le petit combat harmonique" thought up by Mersenne.¹⁷⁵ Descartes' contribution to the debate—two letters: one, brief, of December 1640;¹⁷⁶ the other, longer, of uncertain date¹⁷⁷—does not seek to demonstrate scientifically the music-passions relationship, as Bannius (Joan Albert Ban: 1597-1644) believes, anticipating the dogmatics of the *Affektenlehre*. Descartes does not describe music as the decalogue of rules that are sure to musically stir up the passions: he comments on the composition of a French 17th century maestro, Antoine Boesset. Descartes illustrates to Bannius the pertinence of Boesset's compositional choices which enhance the affective content of the literary places set to music. In his account there is no room for the two quantifiable parameters of sound, tempo and pitch, that the *Compendium* had identified as the cause of pleasure-giving; the word holds a prominent position, and with the word the accents emerge, the centrality of which Descartes, following Mersenne, now underlines in the expression of the different passions.¹⁷⁸ In praising the harmony of Boesset's composition Descartes is praising modern polyphonic music, better able than ancient music to represent the different passions of the soul through the composite texture of the voices. In many-voiced compositions, writes Descartes, one is seeking

the expression of different passions that the words themselves can stir up in different listeners, and also the pleasure of variety.¹⁷⁹

Conflict finds here its representation: the 'aesthetic' is born of the 'pathetic', the pleasure of variety out of the variety of the passions that the various voices move in the different listeners, each with their own history. In the *Compendium* Descartes had written that sad or joyful melodies provide equal pleasure, arguing that the more the elegiac and tragic move us, the more pleasing they are. In the *Passions de l'âme* he once more takes up

¹⁷⁵ Marin Mersenne, *Correspondance*, ed. Paul Tannery *et alii*, 17 vols. (Paris: CNRS, 1933-1988), 9:450. See Daniel P. Walker, "Mersenne's Musical Competition of 1640 and Joan Albert Ban," in Walker, *Studies*, pp. 81-110.

¹⁷⁶ Mersenne, *Correspondance*, 10:325-326; Descartes, *Oeuvres*, 3:255.

¹⁷⁷ See Frédéric de Buzon, "L'esthétique de Descartes dans la correspondance: à propos de la *Lettre à Bannius*," an unpublished paper that I owe to Prof. De Buzon's kindness. De Buzon convincingly argues for postponing Descartes' letter to Bannius ("ma lettre musical") to 1646 instead of 1640, as hastily stated by the Editors of Descartes' *Correspondance*, Charles Adam and Gérard Milhaud, 8 vols. (Paris: Presses Universitaires de France, 1947; reprint ed., Nendeln/Liechtenstein: Kraus Reprint, 1970), 4:226-236.

¹⁷⁸ De Buzon, "L'esthétique de Descartes."

¹⁷⁹ Descartes, *Oeuvres*, 3:832-833: "[...] aliud quaeri ex concentu quàm facilitatem perceptionis verborum;] nempe quaeritur expressio diversorum affectuum qui ab iisdem verbis in diversis hominibus possunt excitari, simulque ex varietate delectatio." See Walker, "Mersenne's Musical Competition," p. 105.

his ancient idea of the coexistence of contrasting passions in the soul. Article 147 “Des emotions interieurs de l’ame” claims that these passions are aroused in the soul exclusively by the soul itself: while they are often elicited by like passions, they are also often engendered by opposing passions:

For example... when we read of strange adventures in a book, or see them represented in a theatre, which sometimes excite sadness in us, sometimes joy, or love, or hatred, and generally speaking all the passions, according to the diversity of the objects which are offered to our imagination; but along with that we have pleasure in feeling them excited in us, and this pleasure is an intellectual joy which may as easily take its origin from sadness as from any of the other passions.¹⁸⁰

Our imagination elaborates the passions aroused in us by the events represented, conjuring up other different, even contrary, passions, and this counterpoint of affectivity is the source, according to Descartes, of profound joy. The sensible music finds an echo in inner music, in the mental theatre of the affections where the ‘I’ represents itself in the alternate motions of the soul. The gland excited by the spirits in the cavity of the brain is in its turn the inner image of the vibrating string which in the outside world is excited and vibrates, engendering by its contrary motions harmony, a synthesis of opposites.

The emotional power of music, its power to move the soul in a controlled way, as desired by Descartes’ correspondent, Bannius, finally found its ‘scholastic’ in the Baroque idea of affections, theoretically argued by Athanasius Kircher (1602-1680) along iatro-mechanic and physiological lines, and by Andreas Werckmeister (1645-1706) along mathematical lines. Eggebrecht turns Kircher’s *musica pathetica* into a physiological and mechanistic theory, but after Descartes, Galileo and Mersenne, Kircher is somewhat an epigone of Renaissance humoral theory. In the same way, the musical mathematics of Werckmeister is a late legacy of the Renaissance mathematical-musical model, outdated by the mechanistic musical science of the Moderns.¹⁸¹

Despite the claims of the ‘theory of affections,’ the music of Descartes is not so foreign to 17th century culture as is generally imagined. The cir-

¹⁸⁰ Ibid., 11:441: “Et lors que nous lisons des avantures estranges dans un livre, ou que nous les voyons représenter sur un theatre, cela excite quelquefois en nous la Tristesse, quelquefois la Joye, ou l’Amour, ou la Haine, & generalement toutes les Passions, selon la diversité des objets qui s’offrent à nostre imagination; mais avec cela nous avons du plaisir, de les sentir exciter en nous, & ce plaisir est une Joye intellectuelle, qui peut aussi bien naître de la Tristesse, que de toutes les autres Passions.” See Descartes, *Philosophical Works*, 1:398.

¹⁸¹ Hans H. Eggebrecht, *Musik in Abenland. Prozesse und Stationen vom Mittelalter bis zur Gegenwart* (Munich: R. Piper GmbH & Co. KG., 1991), pp. 352-360.

culuation of the manuscript of *Compendium musicae* between 1619 and 1650, and, after the *editio princeps* in 1650, its numerous reprintings and translations, ensured that the small Cartesian treatise became widespread in Europe.¹⁸² The English translation of 1653 introduced the culture of the British isles to the music of a continental philosopher famous, for better or for worse, for his dualism and his mechanicism.¹⁸³ The Cartesian 'solution' to the 'mind-body relationship' became the subject of much scientific and metaphysical debate in the second half of the 17th century. As Jamie Kassler has shown, the cognitive metaphor of man as a musical instrument proper to Hobbes, Hooke and North wanted to reaffirm a unitary vision of man and contrast their instrumental realism to Descartes' dualistic approach to man. The problem of how the two substances, mind and matter, interact, threw up new anatomical and physiological explanations on just how, e.g., a particular motion of the air becomes emotion and conscience. In Italian culture such attempts are witnessed by the two major treatises on speculative music in the 17th century in Italy: *Speculationi di musica* (1670) by Pietro Mengoli, and *Del suono, de tremori armonici e dell'udito* (1679) by Daniello Bartoli.¹⁸⁴ In 1668 the French translation of the *Compendium musicae*, published by Nicolas Joseph Poisson (1637-1710) in a miscellaneous volume containing *Dioptrique*, *Meteores* and *Traité de la Mecanique* of Descartes, as well as *Elucidationes physicae in Cartesii musicam* by the same Poisson,¹⁸⁵ presented the music of Descartes as example of his logical method, whereas Poisson's 'physical demonstrations' sought to prove experimentally the mathematical musical theories of the young Descartes. "Enlightened by Descartes' method," states Jean-Philippe Rameau of himself.¹⁸⁶ He had already in the first Book of his *Traité de l'harmonie* (1722) reported the passage of Descartes' *Abregé de musique* translated by Poisson on the guiding principle for the deduction of consonances. Descartes' "perception des rapports," though now referred to the relations between the harmonic sounds demonstrated by Joseph Sauveur,¹⁸⁷ would again find support in Euler and Diderot.¹⁸⁸ And the idea of the

¹⁸² See de Buzon's Présentation to his edition of Descartes' *Abregé*, pp. 20-44.

¹⁸³ See note 47.

¹⁸⁴ See notes 89 and 90.

¹⁸⁵ See note 88.

¹⁸⁶ See Frédéric de Buzon, "La réception du *Discours de la Methode* dans les écrits théoriques de Jean-Philippe Rameau," in *Problématique et réception du "Discours de la Methode" et des "Essais,"* ed. Henry Méchoulan (Paris: J. Vrin, 1988), pp. 277-282.

¹⁸⁷ See note 74.

¹⁸⁸ Leonhard Euler, *Tentamen novae theoriae musicae* (St. Petersburg: Ex Typographia Academiae Scientiarum, 1739), pp. 26-43; Denis Diderot, "Principes généraux d'acoustique," in *Mémoires sur différents sujets de Mathématiques* (Paris: Durand, 1748), edited in Denis Diderot, *Oeuvres Complètes*, 33 vols. (Paris: Hermann, 1975), 2:257.

“musical hieroglyphic,” that Diderot launched against the baroque dogmatics of the affections, was not so indebted to 18th century linguistic theories as not to recall the function of the imagination that Descartes had introduced in the *Compendium* and in the musical letters on the Bannius-Mersenne affair.¹⁸⁹

9 Number to sound

Missing in the *Compendium musicae* of Descartes is one fundamental aspect of sound: “de ipsius soni qualitate, ex quo corpore & quo pacto gratior exeat, agant Physici.”¹⁹⁰ The ‘quality’ of sound, sound as a natural reality, subject of the natural philosophers, remains outside the bailiwick of the mathematician, interested as he is in the quantifiable aspects of sound, “nempe huius differentiae, in ratione durationis vel temporis, & in ratione intensionis circa acutum aut grave.” The passage from number to sound entails on the other hand looking harder into the labyrinth of nature; it means giving up on the ‘qualities’ that inhabit and animate the Aristotelian and Renaissance natural world, and the will to explain nature for what it is or appears to be, matter and motion, re-establishing on its laws, mathematical and physical, the ancient science of the sounding number. *Terminus a quo* towards the modern epistemology of music is still the controversy between Vincenzo Galilei and Zarlino. Against Zarlino’s “well ordained Nature,” which whispers into the ear of man “the consonances in their true and natural Forms,” and has claimed that “by means of human art these Forms should be found as if they were recorded in the natural things, to everlasting memory, well ordained in their own places according to their own degrees; so that Man could know that they were not created by chance, but ordained with great wisdom and not without great mystery,”¹⁹¹ Vincenzo had contrasted the idea of a nature that proceeds “without cognition,” with principles and ends foreign to man, and against Zarlino’s Nature he had set human poesis, the mechanical art devised by

¹⁸⁹ See Béatrice Durand-Sendrail, *La musique de Diderot. Essai sur le hiéroglyphe musical* (Paris: Kimé, 1994).

¹⁹⁰ See note 164.

¹⁹¹ Zarlino, *Sopplimenti*, p. 97: “Questa Sapientia d’ordinare, non d’altri s’impara, che dalla ben’ordinata Natura, la quale hà sempre in tal modo collocate le cose, che non si trovò mai alcun Sapiente, per grande ch’egli fusse, che meglio le ordinasse di lei. Laonde hauendo essa Natura prodvttrice delle cose del mondo fatto noto al Senso dell’udito ne i Suoni & nelle Voci le Consonanze nelle lor vere Forme & natvrali; volse anco, che col mezo dell’arteficio cotali Forme si trouassero, come registrate nelle cose naturali, à perpetua memoria, collocate per ordine, secondo i gradi loro ne i loro proprii luoghi; accioche l’Huomo conoscesse, che non fussero state fatte à caso; ma ordinate con gran sapientia & non senza gran misterio.”

man to pursue an end that is different from nature, or that nature cannot achieve.¹⁹² Vincenzo's son, Galileo Galilei (1564-1642), combined the principles of nature and the principles of mechanics that his father had separated, and for the first time mechanics became the physical and mathematical science of the movement of bodies, natural and artificial.¹⁹³ It was precisely this reformed mechanics that banished the 'qualities' and unveiled the "great mystery," forcing Nature to bring forth the sounding numbers concealed in its womb through Vincenzo's 'sensate experiences' and Gioseffo's 'mathematical demonstrations'.

The science of the 'sounding number' begins with the discovery of consonances in the blacksmith's workshop of the 6th century in the pagan age. Even the modern musical paradigm has its own apologue, the mirror image to that of Pythagoras where our story began. It is the warm apologue of the bird-catcher in *The Assayer* (1623) Vincenzo's son uses to represent the condition of the man of science. A man, with no other experience of sonorous events but that of the song of his birds (*musica irrationalis*), hears the sound of melodious notes in the middle of the night, and thinking it to be a bird makes to capture it; to his surprise, the man discovers a shepherd blowing on a whistle (*musica instrumentalis*). Impressed, the man ventures out into the world in search of other unknown sonorous events, and just when he thinks he has come to know everything (*musica intelligibilis*),

... he suddenly found himself once more plunged deeper into ignorance and bafflement than ever. For having captured in his hands a cicada, he failed to diminish its strident noise either by closing its mouth or stopping its wings, yet he could not see it move the scales that covered its body, or any other thing. At last he lifted up the armor of its chest and there he saw some thin hard ligaments beneath; thinking the sound might come from their vibration, he decided to break them in order to silence it. But nothing happened until his needle drove too deep, and transfixing the creature he took away its life with its voice, so that he was still unable to determine whether the song had originated in those ligaments¹⁹⁴

Pythagoras enters the workshop knowing already what he will find, the universal archetypes of musical sounds; the modern experimenter mistrusts however his knowledge, "so that when asked how sounds were created he used to answer tolerantly that although he knew a few ways, he was sure that many more existed which were not only unknown but unimaginable."¹⁹⁵

¹⁹² See Section 6 in this Introduction.

¹⁹³ Jürgen Mittelstrass, "Nature and Science in the Renaissance," pp. 27-30.

¹⁹⁴ Galileo Galilei, *Discoveries and opinions of Galileo... including excerpts from the Assayer*, trans. Stillman Drake (New York: Doubleday, 1957), pp. 257-258.

¹⁹⁵ *Ibid.*, p. 258.

Galileo was to remember Pythagoras at the end of the first day of his *Discourses and Mathematical Demonstrations Regarding Two New Sciences* (1638). In justly famous pages, Galileo recycles the traditional theory of sounding numbers in his new science of motion.¹⁹⁶ In the second half of the 16th century, Giovanni Battista Benedetti (1530-1590) had already applied the Aristotelian concept of time as a measure of movement to the vibrations produced in the air by the string; the ratios between the times of vibrations quantified the musical consonances, which were explained physically through the periodic movement of sounds.¹⁹⁷ The attack on the 'musical universals' was then continued by Vincenzo Galilei. Experience had shown him how the 'sonorous number' depended on the material conditions of the 'sonorous body': tension of the strings, transversal section, mass of the material, volume of the pipes, and so on. The primacy of motion and matter over number became the premise of Galilean and modern musical science. In his *Discourses* Galileo recasts the physical theory of Benedetti and the experimental observations of the father in a mechanistic theory of consonance, which in the following decades becomes the starting point and the theoretical model for the study of music in the framework of mechanical philosophy.¹⁹⁸ Galileo assimilates the simple harmonic motion in an ideal pendulum to the swinging of the vibrating string, and proves experimentally that the frequency, understood as the number of periodic oscillations of the string in unit time, is the physical cause of the pitch of the consonant sounds. The kinematics of the consonance then becomes the premise for a physiology of auditory perception, limited in the *Discourses* to the behaviour of the tympanic membrane, assimilated to a deformable elastic body capable of oscillating in synchrony with the periodic impulses transmitted into the air by the sonorous body.¹⁹⁹ Musical science is simply a chapter of the mechanics of elastic bodies, and the new paradigm transforms the lexicon and content of the discipline, and its standing in the encyclopedia of knowledge: the ancient science of the sounding number, whose principles were rooted in arithmetic and geometry, is now a physico-mathematical discipline set like optics or astronomy in the modern system of the mechanical laws of nature. After Galileo,

¹⁹⁶ Galileo Galilei, *Two New Sciences*, trans. Stillman Drake (Madison, Wisc.: University of Wisconsin Press, 1974), pp. 99ff; see Walker, *Studies*, pp. 27-33, and Cohen's piece in this Collection.

¹⁹⁷ Giovanni Battista Benedetti, *Diversarum speculationum mathematicarum et physicarum liber* (Turin: N. Bevilacqua, 1585), pp. 277-283; see Palisca, *Scientific Empiricism*, pp. 219-223, and *Humanism*, pp. 257-265; see, also, H. Floris Cohen, "Benedetti's Views on Musical Science and their Background in Contemporary Venetian Culture," in *Giovanni Battista Benedetti e il suo tempo* (Venice: Istituto Veneto di Scienze, Lettere ed Arti, 1987), pp. 301-310.

¹⁹⁸ See Cohen's piece in this Collection.

¹⁹⁹ Galilei, *Two New Sciences*, p. 104.

Mersenne can announce the definitive passage from number to sound: the sounding number is not what mathematicians abstractly consider, “absque materia” (“without matter:”) the number does not produce sound. For Mersenne and Galileo the sounding number denotes the number of periodic vibrations of the air “by which the hearing can be affected and moved.”²⁰⁰

Paradoxically, not so much hearing as vision is the paradigm for the musical reasoning in the *Discourses*. Galileo’s problem is to visualize frequency, to set beneath his Reader’s eyes the physical images of Nature capable of sensibly showing the ratios of frequency among consonant sounds. Today as then the Reader ‘sees’ the experiments which Galileo recounts with sovereign rhetoric within the context of a ‘natural history of sound’, stemming from its generation to its auditory perception. Having opened with the definition of the laws of the swinging pendulum, the musical pages of the *Discourses* close through the image of three pendulums oscillating together, visual metaphor of the pleasure produced by the vibrations of the sounds in the air which regularly strike the ear-drum. At the core of his natural history of sound Galileo introduces some musical experiments, depicting them with extraordinary realism, in a way more impressive than actually seeing them—*enargheia* as a synonym of ‘sensate experience’, visual demonstration. When thirty years later Poisson would try to ‘demonstrate’ Descartes’ *Compendium musicae* with the musical experiments of Galileo’s *Discourses*, he will use the expression ‘physical demonstrations’ (*elucidationes physicae*) in the sense of the Galilean ‘sensate experience’, *repraesentatio quae se ostendit*. In his own rhetorical and experimental structure Galileo has in mind Gaffurio’s plate and Boethius’ story on the Pythagorean discovery of consonances. At least one of the images of Gaffurio’s plate, that of the the glasses filled by water, is the model to one of the experiments in the *Discourses*. Galileo describes the ripples of water on the surface of a resonating glass, which show us the ratios of frequencies of two sounds at the distance of an octave: the waves regularly divide into half, the sounding numbers are visualized through the vibrations of the two sounds on the surface of the water.²⁰¹ Together with the Pythagorean reminiscence, Galileo also recollects here the Stoic analogy between propagation of sounds in the air and circular waves engendered on the surface of the water in the pond by a small stone. The expression “the invention was by chance” (“l’invenzione fu del caso”) Galileo chooses to introduce the second experiment, recalls the expression “for a divine chance” (“divino quodam casu”) Boethius uses with regard to Pythagoras’ encounter with the mythical blacksmiths.²⁰² Like the hammers and anvils, Galileo’s experimental tools—chisel and plate of brass—are of metal and

²⁰⁰ Marin Mersenne, *Cogitata Physico-mathematica* (Paris: Bertier, 1644), p. 261.

²⁰¹ Galilei, *Two New Sciences*, p. 100.

²⁰² *Ibid.*, p. 102; Boethius, *De musica*, I, 10.

common usage, and like Pythagoras' hammers they reveal the ratios of consonances (here of two sounds a fifth apart) as recorded in Nature. The symmetrical lines the chisel etches into the brass in concert with the two sounds show permanently to Galileo's eyes and ours the numbers of frequencies as recorded in the metal, and these images of Nature can win out against the unrepeatability of sonorous events. Chipping off matter from a metal surface using a chisel, as with the Pythagorean hammers, generates sonorities that hold within them profound truths, manifest only to the enlightened to whom a random event becomes meaningful. The cymbal in the room where Galileo handles his metals bears living auditory and visual witness to the experiment with the vibrations of its string that is tuned up to the fifth Galileo has engendered 'by chance'. It is hardly surprising that such a lively tale, which throws the mental eye and ear of the Reader into Galileo's work room, resisted the wear and tear of time for about over three centuries until Walker noticed the mistake in Galileo's report.²⁰³

Between the end of the 16th and the first years of the 18th century the 'experimental philosophy' showed that a string can vibrate in many way at the same time, generating with its fundamental sound the series of its concomitant harmonic sounds: Zarlino's 'perfect harmony' existed in nature as a physical law of resonance. The discovery of the 'natural principle' of harmony became part of the culture of musical theorists only later. For more than a century from the acceptance of the physical-mathematical paradigm, the search for the 'natural principle' of harmony had been separated from the search for its 'musical principle', and it was only in the first half of the 18th century that the two parts of musical science met. When in the Preface to his *Traité de l'harmonie* Rameau states that he wants to reclaim in music the rights that reason has lost to mere practice, he is lamenting the decline of a musical theory that has ignored the lesson of the Ancients, renouncing its ties with science.²⁰⁴ In the *Traité*, Rameau traces musical theory back "à ses principes naturels," reproducing the traditional model of mathematically deducing consonances: he cuts out the ties of music with natural philosophy and, following Descartes, deduces the chords from the successive divisions of the string.²⁰⁵ It is as if between Rameau and Zarlino or Descartes there has been no 'modern science'. Only with his *Génération harmonique* (1737) does Rameau contaminate musical theory with Newtonian science, reformulating the harmonic con-

²⁰³ Walker, *Studies*, pp. 29-30; see also Cohen's piece in this Collection, and Thomas B. Settle, "La rete degli esperimenti galileiani," in *Galileo e la scienza sperimentale*, ed. Milla Baldo Celin (Padua: Dipartimento di Fisica "Galileo Galilei", 1995), pp. 11-62, esp. 35-45.

²⁰⁴ Jean-Philippe Rameau, *Traité de l'harmonie réduite à ses principes naturels* (Paris: Jean-Baptiste-Christophe Ballard, 1722), reprint ed., Jean-Philippe Rameau, *Complete Theoretical Writings*, ed. Erwin R. Jacobi, 6 vols. (Rome: American Institute of Musicology, 1967), 1:1-3.

²⁰⁵ *Ibid.*, pp. 33-34.

cept of “fundamental bass” with the physical one of “fundamental sound.”²⁰⁶ Rameau’s synthesis coincides with the conversion to experimental philosophy of an epigone of the speculative musical tradition, begun more than two thousand years before with the Pythagorean discovery of the consonances. Blending musical theory and experimental philosophy, Rameau brings music to the fore in 18th century European science: he wins for himself and for musical science the praise of d’Alembert in his *Discours préliminaire* (1751) of the *Encyclopédie*, and launches the musical dialectics of the Enlightenment, which leads to the final primacy of the aesthetic paradigm on the ruins of the ancient science of the ‘sounding number’. The historiographical conscience of the winning paradigm wastes little time in liquidating the speculative musical tradition born ‘by chance’ in an artisan’s workshop in the 6th century B.C.—“these vain enquiries,” writes Charles Burney, which have held back the progress of music.²⁰⁷

²⁰⁶ Jean-Philippe Rameau, *Génération harmonique* (Paris: Prault fils, 1737), in Rameau, *Complete Theoretical Writings*, 3:15-29; see Matthew Shirlaw, *The Theory of Harmony. An Inquiry into the Natural Principles of Harmony, with an Examination of the Chief Systems of Harmony from Rameau to the Present Day* (London: Novello & Company, 1917; reprint ed., New York: Da Capo, 1969), pp. 155-161, 164-181.

²⁰⁷ Charles Burney, *A General History of Music. From the Earliest Ages to the Present Period* (London: 1789², reprint ed. 2 vols., New York: Dover, 1957), 2:136.

Tradition

1 Sounding Numbers

Daniel P. Walker

The Harmony of the Spheres

Paolo Gozza

"Desiderio da Pavia" and Renaissance Musical Theory

THE HARMONY OF THE SPHERES*

Daniel P. Walker

The purpose of this chapter is to survey a wide and ancient tradition in order to indicate fruitful lines of research within it. This tradition, namely the Harmony of the Spheres, the *musica mundana* of Boethius, has hitherto been chiefly studied as a literary one, a complex of metaphors and topoi, very thoroughly and brilliantly covered by James Hutton in a long article entitled, too modestly, "Some English Poems in Praise of Music."¹ I want now to try and see when, where and in what ways *musica mundana* has had some importance outside literature, some reality as a part of, or influence on the following fields: ordinary music, astronomy and cosmology, astrology and magic, architecture, mathematics and early modern science.

In this tradition we can distinguish two strands, closely entwined together already in Plato: numerology, number-mysticism, and music as a science, the ideal of a mathematical universe. The two strands clash and begin to separate in the 17th century, for example, in the controversy between Robert Fludd on the one hand, and Kepler, Mersenne and Gassendi on the other, on which there is a good essay by Pauli, though certainly much remains to be done.² This is no doubt an over-simplified framework, but it may be better than nothing as a guide through the bewilderingly huge survey I have embarked on.

It is evident that of the two strands the first is to us the most puzzling, the most foreign to our ordinary habits of thought, and, precisely for this

* First published as "La tradition mathématico-musicale du platonisme et les debuts de la science moderne," in *Platon et Aristote à la Renaissance* (Paris: J. Vrin, 1976), pp. 249-260, the article is printed in revised form in Walker's *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute/University of London, and Leiden: E.J. Brill, 1978), pp. 1-13. On the subject see, also, Eberhard Knobloch, "Harmony and Cosmos: Mathematics serving a Teleological Understanding of the World," *Physis* 32 (1995): 55-89.

¹ James Hutton, "Some English Poems in Praise of Music," *English Miscellany* 2 (1951): 1-63 [now in his *Essays on Renaissance Poetry*, ed. Rita Guerlac (Ithaca and London: Cornell University Press, 1980), pp. 17-73]; cf. John Hollander, *The Untuning of the Sky* (Princeton, NJ: Princeton University Press, 1961); Ludke G. Finney, *Musical Backgrounds for English Literature: 1580-1650* (Westport, Connecticut: Greenwood Press, 1976).

² Carl G. Jung & Wolfgang Pauli, *The Interpretation of Nature and the Psyche* (London, 1955). [See, also, Robert Westman, "Nature, Art, and Psyche: Jung, Pauli, and the Kepler-Fludd Polemic," in *Occult and Scientific Mentalities in the Renaissance*, ed. Brian Vickers (Cambridge: Cambridge University Press, 1984), pp. 177-229].

reason, I think it most important not to neglect it, not to dismiss it contemptuously, before we have made at least a serious effort to understand it, to make some kind of sense out of it. We may of course end up with a negative result, a risk that must be run in any genuinely exploratory research.

Perhaps large areas of numerology were just an aimless, childish and boring game which consists in collecting sets of things whose only common characteristic is having the same number of members—the four elements, the four points of the compass, the four evangelists, etc. But even so, we still have to account for the remarkable persistence of numerology, and for the interest taken in it by so many thinkers, some of them of the highest importance—to name only a few from antiquity and the Renaissance: Plato (the terrible nuptial number in the *Republic*, VIII),³ Macrobius (Commentary on the *Somnium Scipionis*),⁴ Francesco Giorgi,⁵ Robert Fludd,⁶ and even Leibniz. And there is also the vast field of mediaeval number-mysticism, which I know about only second-hand, through the works of Hopper, Abert and Huizinga.⁷

Moreover, there are at least two directions in which numerology does lead to something of interest and value: 1) arithmetical speculations about different kinds of number: square, cube, triangular, prime, perfect, etc.; 2) the importance of certain numbers in Neoplatonic metaphysics and Christian theology: God as the One and the Good, Proclus' henads, Leibniz's monadology, Neoplatonic triads of principles, the Christian Trinity as, for example, in St. Augustine's *De Trinitate*, and on a higher mathematical level, the geometrical analogies of Nicolas of Cusa and Kepler. This trend eventually, in the 17th and 18th centuries, with the advent to the numbers of zero and the ability to deal mathematically with different kinds of infinity, produced some very interesting theologico-metaphysical speculation: Leibniz finding the *creatio ex nihilo* in his binary numbers;⁸ or the Newto-

³ Plato, *Republic*, 546a-d; cf. Paul Tannery, *Mémoires scientifiques*, ed. J.L. Heiberg & H.G. Zeuthen, 17 vols. (Toulouse: E. Privat, 1912-1950), 1:12ff.; Marsilio Ficino, *Opera Omnia* (Basle: Ex Officina Henricpetrina, 1576), pp. 1413ff. [see, also, Michael J.B. Allen, *Nuptial Arithmetic. Marsilio Ficino's Commentary on the Fatal Number in Book VIII of Plato's Republic* (Berkeley/Los Angeles/London: University of California Press, 1994)].

⁴ Macrobius, *Commentarius in Somnium Scipionis*, II, i-iv.

⁵ Francesco Giorgi (Zorzi) Veneto, *De Harmonia Mundi cantica tria* (Venice: B. de Vitalibus, 1525).

⁶ Peter J. Ammann, "The Musical Theory and Philosophy of Robert Fludd," *Journal of the Warburg & Courtauld Institutes* 30 (1967): 198-227.

⁷ Vincent F. Hopper, *Medieval Number Symbolism* (New York: Columbia University, 1938); Hans Abert, *Die Musikanschauung des Mittelalters* (Halle: M. Niemeyer, 1905); Johan Huizinga, *The Waning of the Middle Ages: A Study of the Forms of Life, Thought, and Art in France and the Netherlands in the Fourteenth and Fifteenth Century* (London: E. Arnold, 1950), chapter 15.

⁸ Daniel P. Walker, *The Ancient Theology* (London: Duckworth, 1972), pp. 223-224.

nian George Cheyne's use of different kinds of infinity in his natural theology.⁹ Perhaps one might add to these directions the recent burst of scholarship which, deriving from a few remarks in Curtius' *Lateinisches Mittelalter*,¹⁰ finds numerological patterns in mediaeval and Renaissance poetry. I am a little suspicious of this.

The connexions of the Harmony of the Spheres tradition with some of the subjects I have mentioned are obvious enough: cosmology and astronomy, from Plato's *Timaeus* to Kepler's *Harmonice Mundi*; but others are less evident, and I want now to indicate what they are.

Connexions of a certain kind with ordinary music are quite easy to see. The Harmony of the Spheres has a firm place in the literary tradition of the *Laus Musices*, and such encomia appear regularly near the beginning of ordinary treatises on the theory of music. But what I have in mind are less purely metaphorical links than those made through highly generalized and rather vague concepts of harmony and proportion—links that are more precise and may lead either to practical musical results or to theories of consonance and explanations of the emotional power and meaning of music. The traditional Praise of Music also always contained examples of the marvellous effects of ancient music, such as the story of Timotheus and Alexander.¹¹ Both these themes, *musica mundana* and the *maravigliosi effetti della musica antica*, provide a good example of an important historical phenomenon: a petrified literary tradition, transmitted through many centuries by sheer copying, may suddenly become alive, be taken seriously and practically, as the Effects of Music were by some 16th century humanists, such as Baïf's Academy¹² and the Florentine Camerata,¹³ and as the Harmony of the Spheres was by Ficino¹⁴ and Kepler.¹⁵ How dead as well as petrified this literary tradition became even in antiquity can be seen in Macrobius' *Commentarius in Somnium Scipionis*. Though he faithfully and correctly transmits the ratios of the Pythagorean scale, he does not even

⁹ George Cheyne, *Philosophical Principles of Religion: natural and revealed: in two parts. Part II ... Containing the nature and kinds of Infinites* (London: George Strahan, 1715).

¹⁰ Ernst R. Curtius, *Europäische Literatur und Lateinisches Mittelalter* (Bern: A. Francke, 1948), pp. 493-500.

¹¹ Hutton (see note 1 above), and Daniel P. Walker, "Musical Humanism in the Sixteenth and Early Seventeenth Centuries," *The Music Review* 2 (1941): 1-13, 111-121, 220-227, 288-308 and 3 (1942): 55-71 [now in Walker's *Music, Spirit and Language in the Renaissance*, ed. Penelope Gouk (London: Variorum, 1995)].

¹² Frances A. Yates, *The French Academies of the Sixteenth Century* (London: The Warburg Institute/University of London, 1947), and *Musik in Geschichte und Gegenwart* (=MGG), *sub voce*.

¹³ MGG, *sub voce*.

¹⁴ Daniel P. Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute/University of London, 1958), pp. 14-24.

¹⁵ [Walker, *Studies*, pp. 34-62].

understand that they *are* ratios; he states that you cannot divide a tone, 9:8, in half because 9 is not divisible by 2 into two integers¹⁶—the real difficulty of course is that there is no rational square root of 8.

To return to these links between our tradition and practical music: first, the Harmony of the Spheres may itself be the subject of a piece of music, as it was of the Florentine *Intermedii* of 1589,¹⁷ or it may play a major rôle in a musical-dramatic work such as the *Balet comique de la Royne* of 1581 and the other festivities at this wedding.¹⁸ Secondly, by way of astrology, our tradition was active in Ficino's attempt to create magically powerful songs, his Orphic singing, and in later versions of his magic, such as Paolini's, who applied it to oratory, or Campanella's, in those astrological rites he secretly performed with Pope Urban VIII.¹⁹ We should remember also Ficino's quite impressive *spiritus* theory of the power of music,²⁰ and someone should look seriously at his commentary on the *Timaeus*, from which it appears that he had read in manuscript Ptolemy's *Harmonica*.²¹

Thirdly, the mathematical and astronomical side of the tradition, the effort to make a precise correlation between the ratios of musical intervals and the distances, speeds or orbits of the planets, led in at least one case, Kepler, to interesting and original explanations of the emotional power of music and to support for the practical use of a certain system of intonation, namely, just.²² It is through this question of intonation, to which I will return, that there are important connexions with science, other than the astronomical and cosmological ones, and of course with ordinary music.

Other connexions with science result from the fact that there were opponents of the Harmony of the Spheres tradition, thinkers who rejected the whole mathematical basis of musical intervals, and proposed a purely empirical investigation of the causes of consonance and dissonance, and an empirically established musical scale: among the ancients Aristoxenos,²³ among the moderns Bacon and Campanella,²⁴ and certainly others I do not know about. An examination of these contrasting points of view and of controversies arising from them, mentioned by John Dee in his famous

¹⁶ Macrobius, *Commentarius in Somnium Scipionis*, II, i, 20-2.

¹⁷ *Musique des Intermedes de la "Pellegrina"* ed. Daniel P. Walker (Paris: CNRS, 1963).

¹⁸ Frances A. Yates, "Poésie et musique dans les 'Magnificences' au mariage du duc de Joyeuse, Paris, 1581," *Musique et Poésie* (Paris: CNRS, 1954).

¹⁹ Walker, *Magic*, pp. 204-212.

²⁰ *Ibid.*, pp. 5-11.

²¹ Ficino, "Commentarius in Timaeum," *Opera*, pp. 1456-1457; cf. Paul O. Kristeller, *Supplementum Ficinianum*, 2 vols. (Firenze: Olschki, 1937), 1:51-54.

²² [Walker, *Studies*, pp. 44-57].

²³ Henry S. Macran, *The Harmonics of Aristoxenos* (Oxford: Clarendon Press, 1902), and *MGG*, *sub voce* "Aristoxenos."

²⁴ Walker, *Magic*, pp. 201, 231.

Preface to Billingsley's *Euclid* (1570) as disputes between "Harmonists and Canonists,"²⁵ would surely throw light on the relationship in early modern science between empiricism and more or less *a priori* mathematical theory. Here some work has already been done: there is Barbour's excellent history of tuning and temperament,²⁶ and there are articles by Crombie and Palisca.²⁷ But there is a great deal more to do.

Another of the subjects I mentioned earlier has some close links with celestial and terrestrial music: architecture. First, some Renaissance buildings were designed on musical proportions, as Wittkower has shown;²⁸ and we have Francesco Giorgi's musical plan for the church of San Francesco della Vigna at Venice.²⁹ Secondly, the chapters in Vitruvius on music are Aristoxenian, that is, in opposition to our tradition, and at least one of his Renaissance commentators, Daniele Barbaro, is sharply critical of Vitruvius and in his commentary gives an orthodox Pythagorean musical treatise.³⁰ It would be well worthwhile looking at other commentaries on Vitruvius, of which there are a great many.

The connexions between musical theory and mathematics begin very early, certainly before Plato, with the discovery of the ratios of the perfect consonances, traditionally attributed to Pythagoras. Paul Tannery³¹ argues convincingly that, though some theory of ratios may be more ancient than this, there are very early signs of the influence of musical problems on Greek mathematics, for example, in Euclid V and VI squared or cubed ratios are said to be doubled or tripled, which would be a natural terminology in a musical context, where adding two equal intervals involves squaring their ratios (5th+5th, or $2 \times 5\text{th} = (3/2)^2$). With the discovery of irrational quantities, also attributed to the Pythagoreans, come other probable cases of musical influence on mathematics, such as the early inven-

²⁵ John Dee, "Mathematicall Preface" to *The Elements of Geometrie of... Euclide*, trans. Sir Henry Billingsley (London: John Daye, 1570).

²⁶ J. Murray Barbour, *Tuning and Temperament* (East Lansing: Michigan State College Press, 1953).

²⁷ Alistair C. Crombie, "Mathematics, Music and Medical Science," *Organon* 6 (1969): 21-36 [reprinted with other articles in chapter 10 "The Science of Music" of Crombie's *Styles of Scientific Thinking in the European Tradition*, 3 vols. (London: Duckworth, 1994), 2:783-894]; Claude V. Palisca, "Scientific Empiricism in Musical Thought," in *Seventeenth Century Science and the Arts*, ed. Hedley H. Rhys (Princeton, NJ: Princeton University Press, 1961), pp. 91-137 [now in his *Studies in the History of Italian Music and Music Theory* (Oxford: Clarendon Press, 1994), pp. 200-235].

²⁸ Rudolf Wittkower, *Architectural Principles in the Age of Humanism* (London: The Warburg Institute/University of London, 1949).

²⁹ *Ibid.*, pp. 90ff.

³⁰ Daniele Barbaro, *De Architectura libri decem, cum commentariis* (Venice: Franciscus Franciscus, 1567).

³¹ Paul Tannery, "Du rôle de la musique dans le développement de la mathématique pure," in his *Mémoires scientifiques*, 3:69-89.

tion of methods of successive approximation to $\sqrt{2}$ or other surds, which is more likely to come from efforts to divide the octave or tone in half than from architects or other technicians, who could so easily construct such irrationals geometrically. It is by the way worth bearing in mind that the Greek word for a ratio is *logoj*. For thinkers like Kepler, or a little later Meibom,³² who believed that geometric ideas are coeternal with God, the beginning of the Gospel of St. John may have had a strange meaning: $\tau\mu\eta\nu \epsilon\rho\chi\eta \alpha\upsilon\tau\omicron\iota \delta\iota\omicron\log\omicron\iota$.

This early discovery of musical ratios was unique and momentous, one of the main starting-points of Greek mathematically orientated science. The discovery meant that an immediately given, subjective, sensible quality was found to be exactly correlated with measurements expressible as simple numerical ratios, all having the same pattern, superparticular ($n+1:n$); and this correlation was established empirically by using the monochord. We feel whether an octave or a fifth is in tune or not, and with great accuracy; we get them exactly in tune, then we measure the strings on our monochord, and lo! they are as 1:2, 2:3. The whole world of sensible qualities, e.g. hot, cold, dry wet, might then be explicable in the same way; the ultimate elements, the basic structure of the physical universe might be found to show similar, though not necessarily identical, simple elegant mathematical ratios.

Now the other, still more ancient body of well-established, mathematically expressible observations was of course astronomy. Here we do not have the extraordinary fact of sensible (secondary) qualities corresponding to mathematical ratios, nor is the geometry involved all that simple and elegant. But still, as long as one could "save the phenomena" by means of the simplest and most beautiful figure, the circle, the situation was not too bad, even if the planets needed a lot of epicycles. It was natural, then, to bring the music and astronomy together, and hence we have the harmony of the spheres already in Plato's *Timaeus*³³ and *Republic*.³⁴

The musical ratios which Pythagoras perhaps discovered and which appear in the *Timaeus* are those of the so-called Pythagorean scale, in which all the fifths are just (3:2), there are only major tones (9:8), the semitones are narrow (256:243), and the thirds and sixths are dissonant (81:64; 27:16). This system prevailed, at least in theory, until the 16th century, when it gave way to just intonation. The latter is a scale having the maximum number of just consonances. If all the consonances were just, the

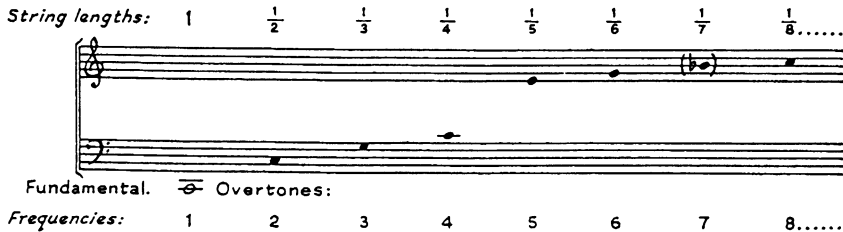
³² Marcus Meibomius, *De Proportionibus Dialogus* (Hafniae: Typis Melchioris Martzani, 1655).

³³ Plato, *Timaeus*, 34b ff. Here the harmony of the spheres is not actually mentioned, but is strongly suggested since, after the musical construction of the *anima mundi*, its strips are bent into an armillary sphere.

³⁴ Plato, *Republic*, 616d ff.

scale would be hopelessly unstable even in the simplest diatonic music, e.g. C, f, a, d, g, C, ends flat by a comma (81:80); or in other words, it is impossible to construct a diatonic scale in which all the consonances are just. Hence the usual form of the scale is one which has a narrow fifth, D to a in the scale of C, and a narrow minor third, D to f. It has major and minor tones (9:8 and 10:9), wide semitones (16:15), and, with the above two exceptions, all the consonances are just, i.e., are intervals given by the natural series of overtones. But it was invented long before anything was known of overtones; for it is already in Ptolemy's *Harmonica*,³⁵ and the scale was often called after his name. The system of just intonation was reached by purely mathematical means, though the sweetness of the consonances was confirmed empirically by the monochord. By using harmonic proportion (if $a > b > c$, $\frac{a}{c} = \frac{a-b}{b-c}$; the harmonic mean between a and c, $b = \frac{2ac}{a+c}$) one can divide the octave into a fifth and a fourth, the fifth into a major and a minor third, the major third into a major and a minor tone.

The harmonic series: 1, 1/2, 1/3, 1/4... also points directly to the overtone series; for this is how a string does in fact divide itself up into vibrating parts, thus producing the overtones, or partials:



It is, I think, surprising that the overtones were discovered so late; one would have thought that anyone just fiddling about with a bowed instrument, let alone playing a trumpet or a tromba marina, would have hit on them. But Descartes, in his *Compendium Musicae*, written in 1618, is only on the brink of the discovery; he notes that the long-known phenomenon of sympathetic vibration also occurs with strings tuned, not in unison, but in an octave or a twelfth.³⁶ In the *Harmonie Universelle* (1636) Mersenne

³⁵ Ptolemy, *Harmonica*, Book 1, chapter 5 [trans. Andrew Barker, *Greek Musical Writings*, 2 vols. (Cambridge: Cambridge University Press, 1984-1989), 2:306-311].

³⁶ René Descartes, *Oeuvres*, ed. Charles Adam & Paul Tannery, 13 vols. (Paris: J. Vrin, 1974), 10:97, 99, 103.

has observed higher partials;³⁷ but even towards the end of his life he is still uncertain about them and puzzled by them—in 1647 he writes to Constantijn Huygens asking him for help in clearing up these problems.³⁸ And as late as 1675 Christiaan Huygens does not get the series quite right: he gives a tenth, instead of a third plus two octaves, for the fifth partial.³⁹

These two systems, which were in competition during the 16th century, Pythagorean and just, are of course mathematical ideals to which musical practice corresponds only very roughly. Nevertheless it does matter which mathematical model one aims at, and the resultant differences in practice are perceptible;⁴⁰ hence the enormous amount written about them in the 16th and 17th centuries. Moreover, instruments with fixed intonation, *i.e.* keyboard of fretted, cannot use either of these systems, but must use some kind of temperament. Here again there were two competing methods: various kinds of mean-tone temperament and equal temperament; but the latter was a necessity for fretted instruments, and the former was almost universally recommended for keyboard instruments. Both kinds of temperament involve ratios including irrational numbers. Mean-tone is based on the principle of dividing just major thirds (5:4) into two equal tones, which therefore have the ratio $\sqrt[5]{5}:2$; such scales have sweet thirds and sixths and narrow fifths. Equal temperament is a division of the octave into twelve equal semitones of the ratio $\sqrt[12]{2}:1$, so that all the intervals are slightly false—the fifths a little narrow and the major thirds a little wide. Aristoxenos had proposed long ago dividing the scale into equal parts; but this, apparently, was to be done by ear, which is not at all easy. By the later 16th century theorists were capable of dealing mathematically with the problems of temperament. It is evident that once logarithms were invented there was a very easy method of obtaining close approximations to these irrationals; and it is another surprising fact that, although Napier's first work on logarithms was published in 1614,⁴¹ they were not used for this purpose until the second half of the century.⁴²

³⁷ Hellmut Ludwig, *Marin Mersenne und seine Musiklehre* (Berlin: Halle, 1935), pp. 40ff.

³⁸ Christian Huygens, *Oeuvres complètes*, 22 vols. (Den Haag: M. Nijhoff, 1888-1950), 1:59-60.

³⁹ *Ibid.*, 19:366-367.

⁴⁰ To convince himself that he can hear the difference between just and Pythagorean thirds and sixths, the reader who owns a violin or 'cello may make the following simple experiment. Having tuned the instrument as accurately as possible, play E on the D-string with the open G-string; then, taking care not to move your finger, play the E with the open A-string. If the major sixth has been made as sweet as possible, it will be found that the finger has to be leaned considerably forward to produce a perfect fourth. The difference between the two E's is a comma (81:80). Then try the experiment the other way round.

⁴¹ John Napier, *Mirifici Logarithmorum Canonis descriptio* (Edinburgh: Ex officina A. Hart, 1614); a description of Napier's logarithms was published in French in Paris in 1624:

We should bear in mind that irrational quantities belong to what was once perhaps an awe-inspiring, mysterious side of mathematics. Think, seriously, of a non-recurring, interminable decimal, *i.e.* one of the orthodox definitions of an irrational quantity; of series that approach ever nearer to a surd, but which we know can never reach it; or of infinite series the sum of which converges towards a rational number; or again of the infinite quantity of rational numbers between any two rational numbers, and so forth.⁴³ Towards the end of the 16th century the mathematician was beset on all sides with different kinds of infinity, not only the infinitely great universe,⁴⁴ and the infinitely small universe if matter is indefinitely subdivisible, but also all these infinite series trailing away eternally towards a number or a surd, and never getting there; whereas previously infinity and eternity had been strictly confined to God. One would therefore expect that the people who first fully realized and accepted that a man-made system was riddled with these pits of infinite depth must have been thinkers of wildly bold, soaring imagination and were likely to be of a deeply religious, mystical cast of mind. And this expectation is in fact borne out: Pascal poising man between the infinitely great and the infinitely small (and “le silence éternel de ces espaces infinis m’effraie;”)⁴⁵ Napier commenting on the Apocalypse;⁴⁶ Kepler worshipping his geometrizing God and using the most extraordinary sexual metaphors;⁴⁷ Leibniz finding the creation in his binary numbers;⁴⁸ Newton, a secret Arian, copying out mystical alchemical treatises.⁴⁹ As Descartes remarked to Mersenne, “la partie de l’esprit qui aide le plus aux Mathématiques, à sçavoir l’imagination, nuit plus qu’elle ne sert pour les spéculations métaphysiques.”⁵⁰ There is in Plato, the main starting-point of this whole tradition, the same combination: poetic imagination and religious feeling, coupled with an intense interest both in genuine mathematics and numerology. This, I think, is one explanation of why number-mysticism and proper mathematics remained so long entwined together. We can contrast this type of mind with someone like

see Marin Mersenne, *Correspondance*, ed. Paul Tannery, 14 vols. (Paris: Presses Universitaires de France, 1945-1980), 1:314.

⁴² [Walker, *Studies*, chapter 7].

⁴³ Friedrich Waismann, *Einführung in das mathematische Denken*, (Munich: Deutscher Taschenbuch-Verlag, 1970³).

⁴⁴ Alexandre Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins Press, 1957).

⁴⁵ Blaise Pascal, *Pensées*, ed. Léon Brunschvig, numbers 72, 206.

⁴⁶ John Napier, *A Plaine Discovery of the whole Revelation of Saint John* (Edinburgh: Ex Officina A. Hart, 1593).

⁴⁷ [Walker, *Studies*, chapter 4].

⁴⁸ See note 8 above.

⁴⁹ See Betty J.T. Dobbs, *The Foundation of Newton's Alchemy* (Cambridge: Cambridge University Press, 1975).

⁵⁰ Mersenne, *Correspondance*, 8:611.

Montaigne, who was basically sceptical and not inclined to religious awe; when Jacques Péletier told him about asymptotic curves, he drew the conclusion that geometry, then considered the most certain of sciences, was therefore unsound.⁵¹

I shall end this chapter by briefly discussing theories of consonance and dissonance. These are a particularly interesting and fertile field of research because they are a cross-roads where several different aspects of our tradition meet: the practice and history of music, aesthetics, mathematics, the scientific investigation into the nature of musical sound. I shall just outline the main problems involved and the main kinds of theory that were put forward from the 16th to the 18th century.

The problems are ones that we are still wrestling with, and they arise because we are dealing at the same time with an historical tradition, the evolution of harmonic language in western music, and also with some unchanging acoustical facts, such as the natural series of overtones and difference-tones. That this series is relevant to harmony is undeniable; one just cannot accept as a pure coincidence that the first five partials give a perfectly spaced major *chord*. But how important this fact has been as a shaping influence, how to explain the minor mode, the possible relevance of the seventh partial to the chord of the dominant seventh, why the $\frac{6}{4}$ chord is treated as a dissonance—all these are questions to which there are no simple or certain answers. As I have mentioned, the existence and nature of the overtone series was only gradually being discovered during the 17th century by scientists such as Mersenne, Huygens and Wallis, but its mathematical equivalents, the harmonic series 1, 1/2, 1/3... 1/6 and the just ratios of the consonances, were firmly established from the time of Zarlino onwards.

There were three main types of theory of consonance at this period:

1) A purely arithmetic theory, such as Zarlino's, based on the mathematically harmonic series and the fact that the ratios of the consonances are contained within the *senario*, the numbers 1 to 6 (with the annoying exception of the minor sixth.) This type of theory had the weaknesses that it had, at that time, no physical basis, and that it could offer no psychological explanation of how the mind could immediately be aware of these ratios. When the existence of overtones was fully established, any such theory was strongly reinforced, as actually happened in the case of Rameau, whose first book on musical theory was published before he had heard of Sauveur's work.⁵² But the purely arithmetic theory persisted in Italy into

⁵¹ Michel Eyquem de Montaigne, *Les Essais*, ed. Pierre Villey, 3 vols. (Paris: F. Alcan, 1922-1923), 2:327 (II, xii).

⁵² Matthew Shirlaw, *The Theory of Harmony. An Inquiry into the Natural Principles of Harmony, with an Examination of the Chief Systems of Harmony from Rameau to the*

the late 18th century with theoreticians such as Vallotti and Padre Martini, who consciously rejected any physical explanations.⁵³

2) Theories based on geometry. These are very rare. I know of only two examples: Kepler, and, much later and independently of him, Giuseppe Tartini, whose first work on musical theory was published in 1754.⁵⁴

3) A theory based on the coincidences in the vibrations of two or more sound-waves. Consonances are graded so that the greatest frequency of coincidence causes the highest degree of consonance. This produces the traditional hierarchy of consonances, in descending order: octave, fifth, fourth, major third, minor third. This type of theory was the prevailing one in our period, and also in the 18th century. The first expounder of it, as far as I know, was Benedetti in 1585, and among its adherents were: Beeckman, Descartes, Galileo Galilei, and Huygens. It had the advantage of being compatible with our first type, and also, as we shall see when looking at Galilei's theories, of offering a psychological explanation of the perception of musical ratios. The great weakness of the theory seems not to have been noticed, namely, that it cannot account for the acceptability of tempered consonances, whose vibrations, after the first pulse, will never coincide.⁵⁵

Present (London: Novello & Company, 1917; reprint ed. New York: Da Capo Press, 1969), p. 134.

⁵³ [Walker, *Studies*, p. 125].

⁵⁴ [Ibid., chapters 4 and 8].

⁵⁵ [Ibid., chapter 3]

“DESIDERIO DA PAVIA” AND RENAISSANCE MUSICAL THEORY*

Paolo Gozza

The musical baptism of Desiderio da Pavia came with the publication in Venice in 1571 of Zarlino's *Dimostrazioni harmoniche*: a musical dialogue which has Desiderio as one of the interlocutors. If Desiderio da Pavia was born in 1571 he probably died in 1594. In that year he did in fact appear for the last time as interlocutor in another musical dialogue, *Il Desiderio*, by Ercole Bottrigari.¹ The Bolognese Humanist meant apparently to pay homage to the illustrious figure by immortalizing him in the title of the best known of his theoretical works. Representative of Renaissance musical culture, the destiny of Desiderio da Pavia is similar to that of other figures of various ages who were associated with musical theories. In the historiographical conscience of the discipline they soon ceased to exist—perhaps, like Desiderio, they never existed, neither in historical fact nor indeed in the minds of Zarlino and Bottrigari. It is so rare to come across concrete situations and men in those portrait galleries representing the history of musical theory, that it seems ingenuous to look for traces of an imaginary and imagined figure like Desiderio da Pavia. Desiderio is nonetheless the natural child of Renaissance musical theory, his recognition will perhaps say something about the thought that brought him to light.

History and rhetoric in Zarlino's 'Dimostrazioni'

The years of our good health had already reached MDLXII and it was the month of April when the most illustrious Sig. Donno Alfonso d'Este, Duke of Ferrara, in order to see a beautiful, noble and rich city, that was not just the glory, splendour and reputation of *la bella Italia* (*beautiful Italy*) but also of the whole of Christianity, and perhaps also for other important affairs of his, came to Venice. Where he was received by our most illustrious Venetian gentlemen with the most solemn pomp and circumstance as is their custom to reserve for high ranking people. This Signore had brought with him the best musicians he had around him: among

* Appeared as “Desiderio di Nazione Lombardo da Pavia e la teoria musicale del Rinascimento,” *Il Saggiatore Musicale* 1 (1994):129-148.

¹ Venice: appresso Ricciardo Amadino, 1594.

whom (leaving aside the others for the sake of brevity) was Francesco Viola, his chapel-master, and my good friend.²

The political event³ and its institutional setting, exalted by the pomp of the dogal ceremony, merge together in the incipit of Zarlirian dialogue with the meeting of certain musical professionals. The details give the narration an authentic, realistic tone:

The latter [*i.e.* Viola] came to see me one day and in one another's company we set off towards the splendid S. Marco Square. There seeing open its famous and rich temple built of beautiful and fine marbles with a wide array of columns, since it was already the time for vespers, we went in: and feasting our eyes for a good while on the beautiful pictures worked there by the great masters of old and modern mosaics, we spoke together of their beauty and the splendour of the temple and the enormous outlay made by the afore-mentioned illustrious gentlemen, like those who have always been religious and devoted to God, to decorate it with those things they regard as necessary and fitting and which lend beauty, dignity and splendour to the divine cult. But as we went on pleasantly discussing a whole host of things, vespers having already finished, who should appear but the honourable M. Claudio Merulo da Correggio, the accomplished organist of the said temple: who, having seen and approached us, and been introduced to Viola, asked us after embracing one another to sit down.⁴

² Gioseffo Zarlino, *Dimostrazioni harmoniche* (Venice: Francesco de i Franceschi Senese, 1571), p. 1: "Gli anni di nostra salute erano già peruenuti al numero di MDLXII et era il mese di Aprile, quando l'Illustrissimo Sign. Donno Alfonso d'Este Duca di Ferrara per cagione di uedere una bella, nobile e ricca città, non solamente gloria, splendore e reputatione della bella Italia, ma anco di tutto 'l Cristianesimo, e forse per altri suoi negoti d'importanza, uene a Vinegia. Onde dalli nostri Sign. Illustrissimi Veneziani con solennissima pompa et regali apparati, sì come è loro costume di riceuere tutte quelle persone che sono di alto affare, fu riceuto. Auea questo Sign. seco menato i migliori musici che appresso di lui si ritrouauano: tra i quali (lasciando gli altri, per non esser lungo) era Francesco Viola suo maestro di Cappella, e mio singolare amico."

³ Camillo Zio, *La solennissima entrata dell'illustrissimo, et eccellentissimo Signor Duca di Ferrara, ne la città di Venetia, cominciando dalla partita di sua eccellenza da Ferrara, per infino al suo ritorno* (Bologna: Pellegrino Bonardo, 1562). The Duke was received in Venice on 12 April, Sunday, and left the 17th, Friday. The five days of Zarlirian dialogue presumably took place from the evening of the 12th to Thursday evening 16 April 1562. On Alfonso II d'Este cf. *Dizionario Biografico degli Italiani* (Rome: Istituto dell'Enciclopedia Italiana, 1960), 2: 337-341 (=DBI).

⁴ Zarlino, *Dimostrazioni*, p. 1: "Questi [*i.e.* Viola] uenutomi un giorno a ritrouare, e presomi in sua compagnia, si auissimo uerso la bellissima piazza di S. Marco. Là onde uedendo aperto il suo famoso e ricco tempio, che di belli e finissimi marmi, con una gran copia di colonne, è fabricato, perciocché già era l'ora del uespero, entrammo in esso: e pascendo la uista per un buon pezzo di tempo, con belle pitture che iui si ritrouano da buoni et eccellenti maestri di mosaico antico e moderno lauorate, insieme andauamo ragionando della lor bellezza, e della ricchezza del detto tempio e della spesa grande che in esso fanno li nominati Signori Illustrissimi, come quelli che sono stati sempre religiosi et a Dio deuoti, per adornarlo di quelle cose che uedono esser necessarie e conueneuoli, e portino bellezza,

The architectonic space of St Mark's basilica sanctions the meeting between the musical representatives of the Estense and Venetian political authorities. A short while after, Francesco dalla Viola,⁵ Claudio Merulo⁶ and Gioseffo Zarlino⁷ gathered round their common venerated Master, the height of the musical establishment and its most celebrated institution:

Since we had mulled for some time over many things both worthy and honourable, as the place demanded, we made the decision to leave and, all of one opinion, headed off to visit M. Adriano Vuilaert, then chapel-master of our most Illustrious Lordship and who lived nearby. Being affected by gout and never leaving the house, our aim was to bring him some relief and comfort with the company of so many of his nearest and dearest friends.⁸

The suffering image of Adrian Willaert,⁹ an omen of his imminent end, closes the historical page of the *Dimostrationsi*. Soon after, these real figures would transform a precarious meeting into a longstanding intellectual exchange. The warm affections would be followed by discussions and demonstrations, and the identities of the friends gathered round Willaert would be reshaped by the position assigned them in the theoretical space of musical thought. A text as well known as it is recurrent, Chapter 33 "Who is a musician" ("Quid sit musicus") in the first Book of Boethius' *De institutione musica*, is the model close to Zarlino's *inventio*. Of the

decoro e maestà al culto diuino. Ma mentre che noi con sommo piacere andauamo molte cose scorrendo, eccoti comparere il gentilissimo M. Claudio Merulo da Correggio, soauissimo organista del detto tempio: il quale uedutoci, accostato che si ebbe a noi, si ponemmo a sedere."

⁵ Francesco dalla Viola (?-1568), master of the Ferrara ducal chapel; cf. *The New Grove Dictionary of Music and Musicians* (=Grove), ed. Stanley Sadie (London: Macmillan, 1980), 5:164.

⁶ Claudio Merulo (1533-1604) was the first organist of the San Marco musical chapel from 1557 to 1584; cf. David Bryant, "La musica nelle istituzioni religiose e profane di Venezia," in *Storia della cultura veneta. Dalla Controriforma alla fine della Repubblica*, 4/1: *Il Seicento*, ed. G. Arnoldi and M. Pastore Stocchi (Vicenza: Neri Pozza, 1983), pp. 433-447.

⁷ On Gioseffo Zarlino (1517-1590), who directed the San Marco musical chapel from 1565 to 1590, I refer the Reader to Francesco Caffi, *Della vita e delle opere del prete Gioseffo Zarlino* (Venice: Orlandelli, 1856), who also touches on the relationships between Zarlino, Willaert, Merulo and Viola.

⁸ Zarlino, *Dimostrationsi*, p. 1: "Il perché essendosi tra noi di molte cose degne et onorate, sicome il luogo richiedeva, per un pezzo ragionato, fatto disegno di partirsi, tutti insieme di un parere prendessimo il camino uerso M. Adriano Vuilaert, allora Maestro di cappella della Illustrissima Signoria, il quale poco lontano dimoraua, per conto di uisitarlo, perciocché, molestato dalle podagre, non si partiuua di casa, a fine che la presenza di tanti suoi amici amoreuoli e carissimi gli apportasse qualche solleuamento."

⁹ Adrian Willaert (ca.1490-1562) was chapel-master in San Marco from 1527 to his death, a position then taken over by Cipriano de Rore in 1563-1564, and afterwards by Zarlino; cf. *Grove*, 20:420-428.

“three kinds of people that relate to music” (“tria genera, quae circa artem musicam versantur,”) only the third is contiguous with music as it is fully devoted to reason and speculation (“quoniam totum in ratione ac speculatione positum est:”) it is the *musicus* “who can judge” (“cui adest facultas... iudicandi.”)¹⁰ The other two, *citharoedus* and *poeta*, instrumentalist and composer, are not musicians. Their contiguity with practice or blind natural instinct makes them “totally unable to speculate” (“totius speculationis expertes,”) or “to produce rational explanations” (“nec quicquam afferunt rationis.”)¹¹ The professional roles defined by Boethius redesign the roles of the interlocutors within the structure of Zarlino’s musical dialogue. At the very peak of his discipline, Zarlino embodies the *musicus* that is depositary of the *propter quid*: he understands the causes and provides an explanation for the facts. At the other extreme, it is easy to recognize in Willaert, Viola and Merulo the instrumentalists who in their proximity to compositional and instrumental techniques carry on their work, “unable to fully understand the reason” (“senza renderne ragione alcuna,”) and hence dependant on “those who say it” for them, just as sense is “subalternated” to reason.

A custodian of tradition, Zarlino introduces a constant, the primacy of *musicus*, to prepare for the reform of tradition: he seals his rhetorical invention by admitting a sociological and literary variant into the Boethian model:

By chance a worthy and honourable stranger arrived, a gentleman friend of M. Adriano, who had the same aim of paying him a visit. This man took delight in Music: but above all else he wanted to hear talk about Art and Science, since for many years he had studied Philosophy and had read many Greek and Latin authors dealing with Music. This man’s name was Desiderio and he was of Lombard nationality from Pavia.¹²

A foreigner, a refined exponent of a noble and cultivated social class, learned in philosophy and reader of Greek and Latin musical sources, Desiderio makes his entry into Willaert’s Venetian house to pay his respects to the Master. He conducts himself urbanely with those present: he asks “who we were, the name of each of us, the surname, the country, and our

¹⁰ Anicius Manlius Severinus Boethius, *De institutione musica libri quinque*, ed. G. Friedlein (Lipsiae: in aedibus B.G. Teubneri, 1867), p. 225.

¹¹ Ibid.

¹² Zarlino, *Dimostrazioni*, p. 2: “A caso arriuò un degno et onorato gentil’huomo forastiero, amico di M.[esser] Adriano, uenuto simigliantemente per cagione di uisitarlo. Questi grandemente si dilettaua della Musica: ma sopra ogni altra cosa, desideraua udir ragionare delle cose dell’Arte e della Scienza, percioché per molti anni innanzi studiato auea nella Filosofia, et auea letto molti autori Greci e Latini, i quali di Musica trattauano. Di questi il nome era Desiderio, et era di nazione lombardo da Pauia.”

particular profession;”¹³ then, “having informed us of his own qualities and conditions,” he turns to Zarlino and begins “a new line of thought.”¹⁴

I truly believe, M. Gioseffo, in the desire I have to be able to resolve certain doubts which have been going round in my head for some years now, after I saw and studied together with many other Music books your *Istitutioni harmoniche*: I could not be more disheartened than I am today. Since I remember many things it seems to me that all I read in many authors, and that I continually hear Musicians reminding me of, precipitates in my soul such confusion that I do not know the things I should cling to and believe in.¹⁵

The “natural desire to know,” that the Aristotelian treatment of metaphysics begins with,¹⁶ is here the antonomasia of the musical Humanist whose education comes from reading the ancient and modern writers on music. Like the Platonic philosopher, Desiderio is a lover of knowledge because of indigence: the doubt sown in his mind by the different opinions of musicians generated the desire to grasp the rational causes underlying musical structures. In the Zarlinian dialogue, Desiderio assumes from the very beginning the role of the learned interlocutor of the *musicus*; “the desire of knowing” becomes the prime mover of a dialogue whose aim is to demonstrate truth in musical things:

Adriano. Reason with us a while about these things, so that we too can argue them when the need arises: because I greatly look forward to the day when the things of Music are demonstrated as they should be.¹⁷

Claudio. I especially desire it greatly: and I will learn the way the Musician goes about demonstrating his conclusions, and I will discover the difference there

¹³ Ibid.: “chi erauamo, il nome di ciascheduno di noi, il cognome, la patria, e la particolare nostra professione.”

¹⁴ Ibid.: [then] “informatoci delle sue qualità e condizioni;” [he... begins] “un nuouo ragionamento.” Zarlino’s sober presentation recalls the most sophisticated literary framework of Humanistic dialogue codified in a Veneto setting in the *Asolani* (1505) by Pietro Bembo, in the *Cortegiano* (1528) by Baldassarre Castiglione and, later, in the *Dialoghi* composed by Torquato Tasso between 1578 and 1595.

¹⁵ Ibid.: “Veramente io credo, M. Gioseffo, al desiderio che io tengo di potermi risolvere di alcuni dubi, che mi uanno per la mente già molti anni sono, dopo che io uidi e studiui insieme con molti altri libri di Musica le uostre *Istitutioni harmoniche*: che non mi potea abbattere melio di quello che oggi mi son abbattuto. Percioché ricordandomi molte cose, mi par uedere che tutto quello ch’io leggo in molti autori, e che di continuo odo da Musici ricordare, mi genera nell’animo tanta confusione ch’io per me non mi so risolvere in molte cose di quello ch’io abbia da tenere e credere.”

¹⁶ Aristotle, *Metaphysics*, I, 1, 980 a-b.

¹⁷ Zarlino, *Dimostrazioni*, p. 6: “ragionateci un poco di queste cose, acciò sappiamo anche noi ragionare, quando farà di bisogno: poiché io desidero grandemente uedere un giorno le cose della Musica dimostrate, come star debbono.”

is between the demonstrations that the Musician makes, which I have never understood, and those that the Mathematician and Geometrician make.¹⁸

Adriano. I beg of you to gladly accept this undertaking: for it will be a great relief for my illness. And I swear to you if I were younger than I am I would like to be a pupil once more. I would do all I could to understand the why of Musical things so that I would be able to give answers to any questions... Nor do I complain about being close to old age: but I do regret that I will die before I start learning.¹⁹

The melancholic reflections of the composer, prelude to a no less melancholic and bitter silence of the practitioners, pave the way for higher and nobler discourses. Where once stood uncertain and subjective opinion, linked with the contradictory evidence provided by the senses, now stands the perfect order of deductive reasoning:

Gioseffo. Because in this matter I would like to debate with you with the demonstration in my hand... since in Music one thing is linked with another, like links joined together in a chain.²⁰

Humanistic dialogue and Euclidean ideal of knowledge renew the subject, form and method of musical thinking. With Desiderio da Pavia we encounter a phenomenon of musical Renaissance.²¹

From 'Le Istitutioni' to the 'Dimostrationsi'

In Zarlino's *Istitutioni harmoniche* of 1558 the "natural desire to know" has not yet donned the noble attire and graceful manners of the cultivated Lombard stranger: it is a discarnate idea of the philosophical lexicon. The theme of the teleology of human beings who aim at achieving "perfection"

¹⁸ Ibid., p. 7: "io in particolare lo desidero molto: perciocché... imparerò la uia che tiene il Musico nel dimostrar le sue conclusioni, e uedrò la differenza che è tra le dimostrationsi che fa il Musico, le quali non ho mai ueduto, e quelle che fa l'Aritmetico e il Geometra."

¹⁹ Ibid.: "ui prego a pigliar uolontieri questa impresa: perché mi sarà un grande soleuamento del mio male. E ui giuro che, se io fusse più giouane di quello che io non sono, uorrei di nuovo diuentar discepolo, e darei opera per sì fatta maniera allo intendere la ragione delle cose della Musica, che non uorrei che alcuno mi dimandasse cosa alcuna che io non lo satisfacesse... Né mi doglio di esser uicino a gli anni della decrepità: ma ben mi doglio che mi conuerrà morire allora che io incomincerò ad imparare."

²⁰ Ibid.: "perché di questa materia io uorrei ragionarui con la dimostrazione in mano... essendo che nella Musica l'una cosa è concatenata con l'altra, di maniera come sono gli anelli, che si trovano congiunti insieme in una catena."

²¹ On the controversial historiographical concept of 'musical Renaissance,' cf. Claude V. Palisca, *Humanism in Italian Renaissance Musical Thought* (New Haven and London: Yale University Press, 1985), pp. 1-22.

provides the opening of Zarlino's dedication to the Venetian patriarch Vincenzo Diedo: science is perfection of the intellect, knowledge "the proper operation of man, by means of which he reaches his own source;" therefore, Zarlino writes, "everyone is naturally drawn to understanding things and never tires or has his fill of investigating their reasons or trying to comprehend the deep secrets of Nature."²² The universality of the syllogism leaves no space for the sociological distinctions of the *Dimostrazioni*. In *Le Istitutioni*, he who excels "bettering all others" on the highroad of "perfection" has before him the "man" who must perforce learn. The title *Istitutioni* reflects the scholastic model of the systemic and totalizing treatise, acronical, from the static organization and monologic enunciation, expression of the impersonal subjectivity of knowledge.²³

In the Proem to *Le Istitutioni* the new Pythagoras, who has begun reducing music "to the honour and dignity that it already enjoyed and that it should quite reasonably be," is "in our times" Adriano Willaert. He has purged music of the "infinite errors" that have accumulated and "has shown an elegant way of composing every musical melody."²⁴ *Le Istitutioni harmoniche* are the theoretical continuation of the practical renewal carried out by Willaert. The alliance of *musicus* with composer defines the reciprocal competences and points to the circle of musical practitioners as addressees of the restored musical institutions. The primacy of the musician is introduced by Zarlino via a comparison with painting, the echo of a text in Boethius' *De musica*:

In the same way it is not enough for whoever wants to be a good painter and earn fame by his painting to use colours approximately if he does not know how to give meaning to his work, so it is not enough, and not very praiseworthy, for whoever wants to make a name for himself as a true Musician to have united consonances if he cannot explain such a union.²⁵

²² Zarlino, "Allo Illustrissimo et Reverendiss... Vincenzo Diedo Patriarca di Venezia," *Le Istitutioni harmoniche* (Venice: [Francesco de' Franceschi], 1558): [knowledge] "è la propria operazione dell'huomo, mediante la quale uiene a congiungersi al suo proprio principio;" [therefore] "ognuno naturalmente è tirato alla cognitione delle cose; né mai si stanca né sazia di andare inuestigando le loro cagioni e di uolere intendere gli alti secreti della Natura."

²³ Cf. Maria L. Altieri Biagi, "Forme della comunicazione scientifica," in *Le forme del testo. La prosa*, ed. Alberto Asor Rosa, (Turin: Einaudi, 1971), 3/II: 891-947.

²⁴ Zarlino, *Istitutioni*, p. 2: [reducing music] "uerso quell'onore e dignità che già ella era, e che ragioneuolmente doueria essere;" [Adriano Willaert] "ha mostrato un ordine ragioneuole di componere con elegante maniera ogni musical cantilena." On the nexus theory/practice in Zarlino see Palisca, *Grove*, 20:646-649, *sub voce*.

²⁵ Ibid.: "Ma uedendo che sì come a chi uuol essere buon pittore, e nella pittura acquistarsi gran fama, non è a bastanza l'adoprar uagamente i colori, se dell'opera che egli ha fatta non sa rendere salda ragione, così a colui che desidera auer nome di uero Musico non è bastante, e non apporta molta laude, l'auer unite le consonanze, quando egli non sappia dar conto di tale unione;" see Boethius, *De musica*, p. 187.

What is asked of the “perfect Musician” is to give meaning to his work; the aim of *Le Istitutioni harmoniche* is that “all those who desire to be included in the ranks of good Musicians may, by accurately reading our work, give meaning to their compositions.”²⁶

The text of the dedication to the Doge Alvigi Mocenigo in the *Dimostrationi harmoniche* is dictated by reasons arising from a changed intellectual climate. The key expression of the text is that the treatise is conceived “for the benefit and usefulness the scholars of other Arts and Sciences will reap in understanding the good and the beautiful.”²⁷ The *Istitutioni* are thought and written mainly, if not exclusively, for the benefit of the uncultivated category of the musical practitioners; the *Dimostrationi* wants to be the contribution of music to universal culture. Addressed to the representatives of the arts and sciences, their purpose is to contribute “by means of Music” to an understanding of what is good and beautiful: understanding of the order of things shown by the geometric order of apodictic reasoning. Unlike the neutral *Istitutioni*, the title *Dimostrationi* underlines the certainty achieved by music through the application of the geometric method to musical reasoning.²⁸

The rhetorical instrument of this methodological awareness of music as science is the appearance of the learned and refined nobleman in Willaert's house. Educated in the classics, Desiderio is not the kind of apprentice allowed to keep silent and listen. Classical dialogic communication is the rhetorical genre best suited to the Humanist, not usual among the professional class of musicians.²⁹ With the introduction of the dialogic genre, the demonstrative technique borrowed from the scientific paradigm of the mathematical disciplines makes its entrance into musical treatise writing.³⁰

²⁶ Ibid., p. 2: “a fin che coloro che ameranno di essere nel numero di buoni Musici possano leggendo accuratamente l'opra nostra render ragione de i loro componimenti.” On the idea of ‘perfect musician’ see also *Dimostrationi*, “Ragionamento Quarto,” p. 210.

²⁷ Zarlino, “Al Serenissimo Principe di Venetia Alvigi Mocenigo,” *Dimostrationi*: [the treatise is conceived] “per il commodo e l'utilità che ne sentiranno i studiosi dell'altre Arti e Scienze nella cognitione del buono e del bello.”

²⁸ Zarlino's choice of geometric order selects as models in musical treatise writing Jacobus Faber Stapulensis [Jacques Le Febvre d'Étaples], *Musica, libris demonstrata quattuor* (Paris: J. Higman et W. Hopilius, 1496), and the *Sectio canonis* by the ps.Euclid, translated into Latin by Giorgio Valla (Venice: per Simonem Bivilaquam, 1497 [1498]), *editio princeps* with Latin translation by Johannes Pena (Paris: Apud Andream Wechelum, 1557). The two works figure in the *Summa Librorum... quos in lucem emittet Academia Veneta* (Venice: In Academia Veneta, 1559); see note 69 below.

²⁹ On Humanistic dialogue, cf. David Marsh, *The Quattrocento Dialogue: Classical Tradition and Humanist Innovation* (Cambridge, Ma: Harvard University Press, 1980); Brian Vickers, “Epideictic Rhetoric in Galileo's *Dialogo*,” *Annali dell'Istituto e Museo di storia della scienza di Firenze* 8 (1983): 69-102.

³⁰ Questions of genre in musical writings, studied in the protomedieval and medieval culture by Lawrence A. Gushee, “Questions of Genre in Medieval Treatises on Music,” in *Gattungen der Musik in Einzeldarstellungen. Gedenkschrift Leo Schrade*, ed. W. Arlt, E.

The model of scholastic reasoning is replaced by the axiomatic order of the deductive method, which passes from the simple to the complex via the preliminary definition of the terms and postulates of reasoning and the subsequent demonstration of the theorems and corollaries.³¹

The unexpected visit of Desiderio ("by chance") stirs up the stagnant waters of musical communication. An extraneous voice filters in from outside into the world of the musicians, bringing the values and cultural aspirations of a politically emancipated social class, capable of making its own the *renovatio musicae* and the reasons of a new literary and scientific paradigm. The impersonal rigidity of roles established by tradition is altered. The anonymous subject of knowledge of *Le Istitutioni* is replaced in the *Dimostrationi* by the Author with his own competences in a precise historical context. Like him, the interlocutors that animate the interpersonal dimension of musical dialogue are men in the flesh, with names and surnames, with their professional status. They are all set against the historical and political background of the free Venetian Republic in an age of the renewal of its political, religious and cultural institutions: the princes of two great Renaissance seignories with their retinue of men, San Marco Square, the Basilica and its polychrome architectonic space, the musical chapel, and the musicians who with their work exalted it, above all the Master nearing the end of his professional and human days.³² Even the music/picture literary citation of *Le Istitutioni* gives way in the *Dimostrationi* to the more recent and pertinent music/architecture relationship, where the superiority of music is underlined "for the subject, and for the certainties of the demonstrations," without which architecture could not exist.³³ Paradoxically, in the new order the role of the *musicus* seems emphasized by the universality of the task. If in the *Istitutioni* Adriano Willaert is the 'new Pythagoras,' in the *Dimostrationi* Gioseffo Zarlino is the 'new Euclid' who reconstructs music theory through the principles and the beautiful order of demonstrative reasoning.³⁴

Lichtenhahn and H. Oesch (Bern-München: Francke, 1972), pp. 365-433, have been ignored in the studies on Renaissance culture, which, however, show a good deal of experimentation of literary forms.

³¹ See Hermann Schüling, *Die Geschichte der axiomatischen Methode im 16. und beginnenden 17. Jahrhundert* (Hildesheim: Olms, 1969).

³² On the 'myth' of Venice in a musical key, cf. Ellen Rosand, "Music in the Myth of Venice," *Renaissance Quarterly* 30 (1977): 511-537; Antonio Foscari and Manfredo Tafuri, *L'armonia e i conflitti. La chiesa di San Francesco della Vigna nella Venezia del '500* (Turin: Einaudi, 1983).

³³ Zarlino, "Al Serenissimo... Alvigi Mocenigo," *Dimostrationi*: [the primacy of music is underlined] "per il soggetto, e per la certezza delle dimostrazioni."

³⁴ *Ibid.*, p. 8: [he who puts] "insieme tante e tante dimostrazioni fatte da altri facendosele sue, et anco li principii, col bell'ordine..." Caffi, *Della vita*, p. 17, calls Zarlino "the legislator in musical theory." The *impresa* that Zarlino wanted as his own is a cube with the motto *Nulla senza me* ("Nothing without me,") "che altro dir non volse che: Niuna

Praise of music, demonstrative dialogue

The first part of *Le Istitutioni harmoniche* is a two-fold introduction to musical science: general encomiastic introduction and special mathematical introduction. The unitary theme which is developed from the Proem on as far as chapter 11 is of an exhortatory nature: the recollection of the normative issues of the discipline paves the way for the change-over from the practical sphere of sense to the speculative sphere of reason. This is the premise for acceding to the secrets of musical knowledge anticipated in the special mathematical introduction, from chapter 12 "How necessary Number is in things" to chapter 44 of the First Part of the treatise.

The epidictic parameters of the Zarlinian *encomium musicae* belong to the genre of exhortatory general introductions to the study of the liberal arts in the Hellenistic and Roman culture inherited from Christian thought.³⁵ The classificatory tendency of scholastic medieval thought arranged the theme in the taxonomic divisions lying behind the organization of material in musical treatise writing.³⁶ Transmitted without any significant variants from a century-old tradition, each of the constants of the *laus musicae* is affected in the Humanist-Renaissance age by an innovative tension. In the *Istitutioni* Zarlino reformulates the order of the various topics of the *encomium*. He anticipates the theme 'ancient music/modern music' in the Proem,³⁷ then the constants follow: 'the origin and certainty of music' (chapter 1), 'the wonderful effects of musical sound' (chapter 2), 'the purpose of music' (chapter 3), its 'usefulness' (chapter 4), 'the definition and divisions of the discipline' (chapters 5 to 10); finally, the distinction 'speculative music/practical music', with its corollary *musicus / cantor* (chapter 11), concludes the coherent theme introduced by the Proem.³⁸

Zarlino's variant of the traditional encomiastic genre lies in the rich literary framework and in the Humanistic recovery of classical sources, only partially present in its scholastic models. Zarlino restores the scholastic musical treatise by introducing on the example of Franchino Gaffurio the elements of Humanist culture. The citation "of many passages of Poets, Historians and Philosophers" anticipates already in the title of *Le Istitu-*

cosa ha l'essere, né può durare o permanere senza l'armonia" ("that simply means that: Nothing exists, nor can persist or last without harmony;") cf. Giovanni Maria Artusi, *Impresa del molto r. m. Gioseffo Zarlino* (Bologna: Appresso Gio. Battista Bellagamba, 1603), p. 9.

³⁵ James Hutton, "Some English Poems in Praise of Music," *English Miscellany* 2 (1951): 1-63, now in his *Essays on Renaissance Poetry*, ed. Rita Guerlac (Ithaca-London: Cornell University Press, 1980), pp. 17-73.

³⁶ Leo Schrade, "Music in the Philosophy of Boethius," *Musical Quarterly* 33 (1947): 188-200; Gushee, *Questions of Genre*, passim.

³⁷ Zarlino, *Istitutioni*, "Proemio," p. 1 ff.

³⁸ *Ibid.*, pp. 3-21.

*tioni*³⁹ the Humanistic ideal of an ancient poetic sapiential age, where poetry and music were divine gifts offered to inspired wise men to take mankind from a wild state and reunite men with the laws of the city.⁴⁰ The Proem to the treatise begins with the fresco of the epochal passage of mankind from a primitive wild condition to human life, characterized by the evolution of natural language to the musical language of the wise men-poets. In the sapiential context of the *prisca theologia*, "Music (was) a supreme and singular doctrine," "Musicians being held in high esteem, and receiving inestimable reverence," and "without any difference they were nominated Musicians, Poets and Wise-Men."⁴¹ "The evil of the times" and "the negligence of mankind" have produced the present "infamous baseness." The comparison is not the stale repetition of a rhetorical passage whose last image is the thought of Plato. Playing with the hierarchy of the encomium's topics, Zarlino in the incipit of *Le Istitutioni* highlights the theme 'ancient music/modern music' to affirm the need to renew musical theory in harmony with its ancient models.

If Humanistic philology infuses the conventional epideictic genre with new life, the Pythagorean philosophy of mathematics renews the conventional arithmetic introduction to the use of the *sounding numbers*. Zarlino's models are Boethius' *De arithmetica* and *De musica*, and earlier musical treatise writing renewed by Gaffurio.⁴² The contents are conventional: 'monadic unity as the principle of being' (chapter 12), 'kinds of number' (chapter 13), 'sounding numbers' (chapters 14 to 16), 'the division of quantity' (chapter 17), 'the subject and classification of music' (chapters 18 to 20), 'the theory of proportion,' 'genres of proportion and operations with proportions' (chapters 21 to 35), 'the doctrine of proportionality' (chapters 36 to 44). As in the general encomiastic introduction, Zarlino updates tradition in the special mathematical introduction, too. The variant concerns the deduction and classification of the consonances in the traditional Pythagorean and Boethian arithmetical approach: the *quaternario* (i.e. the numbers from 1 to 4) is replaced by the *senario*, (the numbers

³⁹ *Istitutioni harmoniche... nelle quali; oltre le materie appartenenti alla musica; si trouano dichiarati molti luoghi di Poeti, d'Historici, & di Filosofi; si come nel leggerle si potrà chiaramente vedere.*

⁴⁰ It is the Humanistic myth in the unity of poetry and music as ancient wisdom which in musical literature is associated with the theme of the 'extraordinary effects of ancient music;' cf. Daniel P. Walker, "Orpheus the Theologian and Renaissance Platonists," *Journal of the Warburg and Courtauld Institutes* 16 (1953): 100-120.

⁴¹ Zarlino, *Istitutioni*, p. 1.

⁴² Cf. Flora R. Levin, *The Harmonics of Nicomachus and the Pythagorean Tradition*, American Classical Studies 1 (Philadelphia: Pennsylvania State University, 1975); Palisca, *Humanism*, chapter 9 "Gaffurio as a Humanist," on pp. 191-225.

from 1 to 6) as theoretical justification of the thirds and sixths in the modern vocal polyphonic music.⁴³

The conventional themes of the First Part of *Le Istitutioni* are missing in Zarlino's *Dimostrationi harmoniche*. The themes of the general encomiastic introduction and of the special mathematical introduction give way to a different logical order of reasoning. The start of musical dialogue is still the comparison 'ancient music/modern music' but the theme is not a rhetorical topos, it is a real live problem in the mind of the protagonists. It is "Desiderio da Pavia" who proposes the subject that the five days of musical dialogue revolves around:

And to tell you just one, which fills me with doubt, I find that Pythagoras by denying he was able to get past the Quadruple... did not agree that those intervals that have the form of numbers greater than the Quaternary were consonants, an opinion which was held by many.⁴⁴

Desiderio found it in Euclid "prince of Mathematicians in his Introduction of Music," in Aristoxenus and in Ptolemy: "And since I see and hear from you Musicians that the contrary is the case, I do not know what to make of it."⁴⁵

The appeal to musicians finds an immediate response in Willaert, Viola and Merulo: the comparison established by Desiderio points out the distance between a theory that expunges thirds and sixths as dissonances and a practice where, as Willaert says, "all the charm and grace of Music, and I would also say all its variety," is "located in the two minor consonances of the fourth, that is in the third and the sixth."⁴⁶ In his compositions Willaert made frequent use of thirds and sixths, avoiding "as best I could using such consonances in the low part... though I could not give any reason for that, except feeling that they did not satisfy me."⁴⁷ The question is of pertinence to the theoretician, the dubious testimony of the sense makes room for the infallible certainty of reason:

⁴³ Zarlino, *Istitutioni*, pp. 21-57.

⁴⁴ Zarlino, *Dimostrationi*, p. 2: "E per diruene una, che mi fa molto dubitare, ritrouo che Pitagora negando di potersi passare oltra la Quadrupla... non acconsentiu che quelli interualli, i quali hanno la forma loro da i numeri che sono maggiori del Quaternario, fussero consonati. La quale opinione fu tenta da molti..."

⁴⁵ Ibid.: "E perché uedo in fatto et intendo da uoi Musici essere il contrario, però non so in qual maniera posa credere."

⁴⁶ Ibid., p. 3: "tutta la uaghezza e la leggiadria della Musica, e dirò anco ogni sua diuersità...", "posta nelle due consonanze minori della diatessaron, cioè nel ditono e nel semiditono."

⁴⁷ Ibid., p. 5: "... più che ho potuto, di porre cotali consonanze nella parte graue... quantunque io non ne sapesse rendere ragione alcuna, ma udiua che non mi contentauano a pieno il senso."

There are also other observances, my Sir, in your compositions which you have learned by means of your senses, which are not of little importance, which if you cannot give a reason for, there are many others who will give it for you.⁴⁸

The severe Boethian premise persists, attenuated in the *Dimostrazioni* by the dialogic form and demonstrative reasoning. Maieutic dialogue and anamnesis, on the one hand, geometrical-demonstrative method, on the other, come together to bridge the gap between sense and reason and attenuate the relationship of authority.⁴⁹ When Zarlino signals his intention to premise the demonstration of music with “that which is demonstration and what it consists of,”⁵⁰ he represents Willaert, Viola and Merulo in contact with their own experiences and personal memories:

Francesco. This appeals to me a good deal: because even if I have heard a few times that which is demonstration... this not being my profession, I can no longer remember.⁵¹

Adriano. You have to do it anyway: because I still don’t fully remember these things, even if when I was young I heard them in my studies at Paris when I studied the imperial Laws.⁵²

Claudio. It will also appeal to me greatly: because I believe I know very little of these things even though I heard many of them from discussions with those learned men I am constantly in touch with, for which reason I will remember something and keep it in mind.⁵³

⁴⁸ Ibid.: “Vi sono anche delle altre osseruanze, Messere, nelle uostre composizioni, le quali aucte imparato col mezo del senso, che non sono di poca importanza, delle quali, si bene non ne sapete dir la ragione, non mancano quelli che la dicono per uoi.”

⁴⁹ On the relationship *ratio/sensus* in the musical tradition, see Klaus-Jürgen Sachs, “Boethius and the Judgement of the Ears: A Hidden Challenge in Medieval and Renaissance Music Theory,” and Michael Fend, “The Changing Functions of “Senso” and “Ragione” in Italian Music Theory of the Late Sixteenth Century,” in *The Second Sense: Studies in Hearing and Musical Judgement from Antiquity to the Seventeenth Century*, ed. Ch. Burnett, M. Fend and P. Gouk (London: The Warburg Institute, 1991), respectively on pp. 169-198 and 199-221.

⁵⁰ Zarlino, *Dimostrazioni*, p. 7: “... quello che sia dimostratione, e di che cosa si compone...”

⁵¹ Ibid., p. 8: “Questo mi piace sommamente: perché, se bene può essere che io abbia vdito alle fiate quello che sia dimostratione,... tuttauia, per non essere mia professione, non me ne posso così a pieno ricordare.”

⁵² Ibid.: “Lo dovete fare per ogni modo: perché ancora io non mi ricordo troppo bene queste cose, se bene essendo giouane le vdii nel studio di Parigi, quando mi diedi al studio delle Leggi imperiali.”

⁵³ Ibid.: “Ancora io l’aurò in grande piacere: perché di queste cose credo saperne poche, quantunque io ne abbia vdito molte da i ragionamenti di quelli huomini eccellenti co i quali pratico di continuo, onde mi uerrò a ricordare qualche cosa, e la terrò bene in memoria.”

The pattern of thought which introduces *Dimostrazioni harmoniche* is therefore an anamnesis of the stages of Aristotelian and Neoplatonic reflection on science. The starting point of *Le Istitutioni*, inspired by Aristotle's *Metaphysics*, is extended in the *Dimostrazioni* to the procedures of demonstrative reasoning, provided by Aristotle's *Posterior Analytics* and Proclus' *Commentarius in primum Euclidis Elementorum*, the canonical texts of the Renaissance debate on the mathematical disciplines.⁵⁴ Desiderio's comment goes to the heart of Zarlino's reasoning: "I see something almost new: that in the reasonings of Music one speaks also about things belonging to Philosophy."⁵⁵ "Do you not know, Sir," Gioseffo answers, "that for music to be a part of mathematical Science, and a natural part... it is subjected to Philosophy?"⁵⁶ Aristotelian philosophy of science and Platonic dialogic form exonerate the rhetorical genre of the traditional *encomium*, giving rise to the modern scientifique genre of demonstrative dialogue.

Music theory, modern science

Before shaping demonstrative dialogue, 'the natural desire to know' is a metaphor for the renewal of the mathematical disciplines in the Veneto culture in the second half of the 1500s. In his *Oratio ad Philosophiam Virtutemque ipsam Adhortatoria*,⁵⁷ recited at the Accademia Patavina dei Potenti, Francesco Barozzi begins with the Aristotelian phrase, premise and foundation for the sciences and philosophy.⁵⁸ In his subsequent *Oratio habita in celeberrimo Gymnasio Patavino* (1559),⁵⁹ dedicated to Daniele Barbaro, Barozzi acknowledges that divine Providence and "that natural desire to know which is proper to every man" ("illud, quod in quocunque homine natura insitum est sciendi desiderium,") led him to teach, support and succour "the mathematical disciplines which here [at the University of

⁵⁴ Ibid., pp. 8-18; cf. William A. Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton: Princeton University Press, 1984), pp. 99-148. Zarlino read Proclus in the translation by Francesco Barozzi, *Procli Diadochi... in primum Euclidis Elementorum librum Commentariorum ad universam mathematicam disciplinam principium tradentium libri III* (Padua: exc. Gratosus Perchacinus, 1560).

⁵⁵ Zarlino, *Dimostrazioni*, p. 9: "... io uedo quasi una cosa noua: che nelli ragionamenti di Musica si parla anco delle cose appartenenti alla Filosofia."

⁵⁶ Ibid.: "Non sapete, Sig., che la musica, per essere Scienza matematica parte, e parte naturale... è sottoposta alla Filosofia?"

⁵⁷ Padua: Gratosus Perchacinus, 1558, c. 9r.

⁵⁸ Cf. Paul L. Rose, "A Venetian Patron and Mathematician of the Sixteenth Century: Francesco Barozzi (1537-1604)," *Studi veneziani* 1 (1977): 119-178.

⁵⁹ Printed in Barozzi's *Opusculum, in quo una Oratio, et duae Quaestiones: altera de certitudine, et altera de medietate Mathematicarum continentur* (Padua: excudebat G. Perchacinus, 1560).

Padua] are missing and dispersed” (“mathematicas disciplinas abolitas hic [sc. in Gymnasio Patavino] iam prope, atque deperditas.”)⁶⁰ Barozzi’s arguments in defence, and for the restoration of the nobility and usefulness of mathematics are the arguments of Proclus’ *Commentary* to the *Elements* of Euclid translated by Barozzi, in which the Aristotelian ‘natural desire to know’ becomes the Platonic “Love that engenders and preserves the sciences” (“Amor author et servator scientiarum.”)⁶¹ The ranking of Aristotle alongside the “divine Plato” updates the *comparatio traditio*⁶² along the lines of a widespread tendency among mathematicians of the second half of the century: the Aristotelian theory of scientific demonstration and its application to Euclidean geometry join up with a Platonic and Neoplatonic philosophy of mathematical understanding. It is the new phase in the mathematical Renaissance introduced into Veneto culture at the beginning of the century by Luca Pacioli, Giorgio Valla and Bartolomeo Zamberti: the humanistic programme of retrieving old mathematical sources merges with the discussion on the certainty of mathematical knowledge, whose core is ‘the natural desire to know’ that preserves and restores all.⁶³

The direction Barozzi gave mathematics as the fulcrum for the reform of knowledge had a deep effect on Veneto culture. Zarlino’s epistemological premises to his dialogue⁶⁴ run through the writings of Barozzi, Pietro Catena (died 1576) and Giuseppe Moletto (1531-1588):⁶⁵ the ‘triadic nature of being’ and ‘tripartition of speculative philosophy;’ the mathematical disciplines as ‘middle sciences’ between physics and metaphysics; the

⁶⁰ Ibid., c. 4v.

⁶¹ Ibid.: “Verum si Amor res omnes efficiendi, et servendi vim habet, cuique satis, superque perspicuum est, eum scientiarum quoque autorem, at custodem esse,” c. 3 (“Indeed if Love can engender and preserve all things, it is clear enough to everyone that Love is also author and keeper of the sciences;”) “In qua quidem aetate cum rudes illi [sc. homines] eo, quo Deus Mundum prosequitur Amore primum, deinde naturali hominem sciendi desiderio excitati, admirari, obstupescere coepissent,” cc. 3-4 (“In that age those wild men, being first excited by that Love with which God makes the world go round, then by the desire to know that is natural to mankind, began to be admired and to wonder.”) See, also, Barozzi, *In Primum Euclidis*, cc. 3^r-5^v.

⁶² On the ‘comparative tradition’ between Plato and Aristotle, cf. Frederick Purnell, Jr., “Jacopo Mazzoni and Galileo,” *Physis* 14 (1972): 273-294; Idem, “The Theme of Philosophic Concord and the Sources of Ficino’s Platonism,” in *Marsilio Ficino e il ritorno di Platone. Studi e documenti*, ed. Gian Carlo Garfagnini, 2 vols. (Florence: Olschki, 1986), 2:397-415.

⁶³ Cf. Paul L. Rose, *The Italian Renaissance of Mathematics: Studies on Humanists and Mathematicians from Petrarch to Galileo* (Genève: Droz, 1975).

⁶⁴ *Dimostrazioni*, “Ragionamento Primo,” pp. 8-18.

⁶⁵ Cf. Adriano Carugo, “L’insegnamento della matematica all’Università di Padova prima e dopo Galileo,” in *Storia della cultura veneta* (see note 6 above), pp. 164-169, 170-185. On the relations between Zarlino and Moletto, cf. Paolo Sanvito, “Le sperimentazioni nelle scienze quadriviali in alcuni epistolari zarliniani inediti,” *Studi musicali* 19 (1990): 305-318.

‘nobility of mathematics’ for their demonstrative certainty; the ‘positioning of music’ among the middle sciences; and, finally, the theme of the ‘order and structure of the demonstrative method,’ and the consequent tendency to identify the Euclidean model as a paradigm for all the disciplines in the encyclopedia.⁶⁶ Barozzi, Catena and Moletto are some of the “modern Mathematicians” whose example Zarlino says he wants to follow in the final page of his “Ragionamento Primo,” introducing the first day of the *Dimostrazioni harmoniche*:

But to follow the order championed by our elders and by modern Mathematicians I will begin with the definitions in order; I would list the axioms, or maxims, or rather the so-called common opinions; and finally the questions without which I could prove little or nothing.⁶⁷

The union of the axiomatic method with the humanistic dialogue in Zarlino’s *Dimostrazioni*, where civil conversation is opened up to the rigour of mathematical demonstrations, is the literary synthesis of an intellectual experience. A dedicatee of Zarlinian dialogue is Alvise Mocenigo. Ambassador of the Serenissima to Charles V, doge in 1570, Mocenigo was a member of Federico Badoer’s ‘Accademia Veneziana della Fama’ (1557-1562) where Zarlino was enrolled in the “Rooms of Mathematicians” (“Stanze dei Matematici,”) in the category “Musicians.”⁶⁸ Barozzi, Moletto and Barbaro, Francesco Patrizi and Bernardo Tasso, Agostino Valier and Carlo Sigonio, among others, were connected in different capacities to the syncretic programme of the Academy where love of the old and hermetic tendencies, humanistic rhetoric and encyclopedism, emphasis on mathematics and Platonism co-exist under the sign of *harmonia* and the myth of *renovatio*.⁶⁹

⁶⁶ For example: Pietro Catena, *Oratio pro idea methodi* (Padua: Gratiopus Perchacinus, 1563).

⁶⁷ *Dimostrazioni*, p. 18. “Ma per seguitar l’ordine tenuto da i nostri maggiori, e da i moderni Matematici ancora, porrò primieramente le definizioni per ordine; depoi le dignità, o massime, o ueramente comuni pareri che dire li uogliamo; et ultimamente le dimande: senza le quali poco, anzi nulla potrei dimostrare.”

⁶⁸ Domenico M. Pellegrini, “Breve dissertazione previa al sommario della accademia veneta della Fama,” *Giornale dell’italiana letteratura* 22 (1808): 3-19, 20-32, and 23 (1808): 49-68, 113-128, 193-212 (Zarlino was registered there as “Iseppo Cerlino,” p. 63). See, also, Ian Fenlon, “Zarlino and the Accademia Venetiana,” *Italian Academies of the Sixteenth Century*, ed. David S. Chambers and François Quiviger (London: The Warburg Institute/University of London, 1995), pp. 79-90. For Federico Badoer (1519-1593), see *DBI*, 5:106-108.

⁶⁹ On the Academy of Badoer, besides Pellegrini, cf. Paul L. Rose, “The Accademia Venetiana: Science and Culture in Renaissance Venice,” *Studi Veneziani* 11 (1969): 191-242, and Lina Bolzoni, “L’Accademia Veneziana: splendore e decadenza di una utopia enciclopedica,” in *Università, Accademie e Società scientifiche in Italia e in Germania dal Cinquecento al Seicento*, ed. L. Boehm and E. Raimondi (Bologna: Il Mulino, 1981), pp.

It has been pointed up the emergence, as an effect of the 'Accademia della Fama' on scientific thought, of "a curious literary-Humanist science" whose demise was brought about by Galileo.⁷⁰ A cultural synthesis, Zarlino's *Dimostrazioni* leads to the 'new science' which lends value to the "literary-humanistic science" of the late 16th century rather than making it obsolete. Galileo discovers in the dialogic form the literary genre for locating scientific discourse and bringing about the "contamination between dialogue and Euclidean geometric treatise."⁷¹ The *Dimostrazioni harmoniche* is the most extraordinary precedent of this contamination between literary choice and demonstrative discourse: in this respect, more than Vincenzo Galilei's *Dialogo della musica antica, et della moderna* (1581), Zarlino's *Dimostrazioni* is a source of Galileo Galilei's scientific dialogues.⁷²

This is a point I would like to underline. To relate musical theory to modern science, historians of musical science and musicologists have adopted an historiographical method dear to general historians of science. They have identified in the sources certain elements of 'modernity:' 'experimental attitude' vs 'Pythagorean numerology,' 'mechanical theory' vs 'arithmetical theory of consonance,' and so on, and have built their histories of musical science on this somewhat limited evidence, taking the literary structure of musical treatise writing as accessory and neutral aspects of the scientific project. In another respect, historians of musical theory have essentially founded their discipline on the historiographical categories of anticipation and forerunning. Marginalizing contexts and situations, they have constructed histories where their heroes, like rings in a chain, are placed in order one after the other as a function of the outcome of future musical thought.⁷³ Historians of musical theory, musicologists and histori-

117-167. The eclectic music publishing programme of the Accademia Veneta includes works varying from Francesco Giorgio Veneto (Francesco Zorzi), *De Harmonia mundi* (1525) "translated from Latin," to Ptolemy, Porphyry, Aristides Quintilianus, Faber Stapulensis, Glareanus and Foliano (held in great esteem by Zarlino; see Palisca, *Humanism*, pp. 235-236); cf. Fenlon, "Zarlino and the Accademia Venetiana." Francesco Zorzi's cabalistic Neoplatonism and the musical treatise writing tradition come together in Fabio Paolini's 'Accademia degli Uranici' (1587-1593), on which see Daniel P. Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute/University of London, 1958), pp. 112-119.

⁷⁰ Rose, *The Accademia Venetiana*, pp. 199-201.

⁷¹ Maria L. Altieri Biagi, "Scrittori di scienza e generi letterari," in *Scienza e letteratura nella cultura italiana del Settecento*, ed. R. Cremante and W. Tega (Bologna: Il Mulino, 1984), p. 325.

⁷² See Vickers, "Epideictic Rhetoric in Galileo's *Dialogo*," pp. 74-75.

⁷³ E.g., Matthew Shirlaw, *The Theory of Harmony: An Enquiry into the Natural Principles of Harmony, with an Examination of the Chief Systems of Harmony from Rameau to the Present Day* (London: Novello & Company, 1917; reprint ed., New York: Da Capo Press, 1969).

ans of science have in this way helped create the image of a musical thought that proceeds in a straight line, sheltered from contamination, ready to leave to one side what is not musical. Finally, the history of musical aesthetics has served to conceal the cross-overs of music with modern science, taking late 18th century musical aesthetics as the starting and not arrival point of musical culture. I think it is for these or similar reasons that such histories represent a single Zarlino whose ideas do not change substantially from *Le Istitutioni* to the *Dimostrationi* and to the *Sopplimenti musicali*. Perhaps it is also in this way that figures like “Desiderio da Pavia” can disappear from today’s historiographical conscience.

Tradition

2 Music & Spirit

Brenno Boccadoro

Marsilio Ficino: The Soul and the Body of Counterpoint

Penelope M. Gouk

Music in Francis Bacon's Natural Philosophy

MARSILIO FICINO: THE SOUL AND THE BODY OF COUNTERPOINT*

Brenno Boccadoro

“Harmony” in Ficino’s writings: is it music or metaphysics? The overwhelming presence of historians of philosophy in the Ficino literature, joined to a certain musicological hardheadedness in separating the affective from the syntactic elements, has inevitably led interpreters to the conclusion that Ficino’s investigation into this realm of affections-theory has little in common with concrete sound. Thus his contact with 15th century music is overshadowed by considerations of an essentially philosophical order.¹ Indeed, the word “music” in the Neoplatonic

* I wish to acknowledge my appreciation to Professor Claude Palisca for his reading and translation of this article.

¹ Paul Kristeller in the immediate post-war period already noted regretfully that his edition of the little Ficinian treatise, *Epistola de rationibus musicae*, published in his *Supplementum ficinianum*, 2vols. (Florence: Leo S. Olschki, 1973), 1:51-56, had not yet aroused any reaction in musicological circles: Paul O. Kristeller, “Music and learning in the Early Italian Renaissance,” *Journal of Renaissance and Baroque Music* (now *Musica Disciplina*) 1 (1946-47): 270. In Kristeller’s selected bibliography of 1984, eight out of sixteen titles concern the visual arts, fifteen esthetics, and four music, among which, apart from Kristeller’s “Music and Learning,” he lists: Otto Kinkeldey, “Franchino Gafori and Marsilio Ficino,” *Harvard Library Bulletin* 1 (1947): 379-382; Daniel P. Walker, “Ficino’s Spiritus of Music,” in *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute, 1958); William R. Bowen, *Music and Number: An Introduction to Renaissance Harmonic Science* (Ph.D. dissertation, University of Toronto, 1984). In subsequent years the following saw the light: William R. Bowen, “Ficino’s Analysis of Musical Harmonia,” in *Ficino and Renaissance Neoplatonism*, ed. Konrad Eisenbichler and Olga Zorzi Pugliese (Ottawa, Canada: University of Toronto Italian Studies, 1986), pp. 17-27; Gary Tomlinson, “Musical Modes and Planetary Song, 1480-1520,” *Atti del XIV Congresso della Società Internazionale di Musicologia*, Bologna, 1987: *Trasmissione e ricezione delle forme di cultura musicale*, 3 vols. (Turin: EDT, 1990), 3:183-188; Gary Tomlinson, “Preliminary Thoughts on the Relations of Music and Magic in the Renaissance,” in *In cantu et in sermone: For Nino Pirrotta on His 80th Birthday*, ed. Fabrizio Della Seta and Franco Piperno (Florence: Leo Olschki, 1989), pp. 121-139; Paolo Gozza, ed., *La musica nella rivoluzione scientifica del Seicento* (Bologna: il Mulino, 1989); Sabine Ehrmann, “Marsilio Ficino und sein Einfluß auf die Musiktheorie: zu den Voraussetzungen der musiktheoretischen Diskussion in Italien um 1600,” *Archiv für Musikwissenschaft* 18 (1991): 234-249; Angela M. Voss, *Magic, Astrology and Music: The Background to Marsilio Ficino’s Astrological Music Therapy and His Role as a Renaissance Magus* (PhD diss.: City U., London, 1992); Gary Tomlinson, *Music in Renaissance Magic* (Chicago and London: The University of Chicago Press, 1993); Wolf Frobenius, *Einleitung: Zur Begriffsgeschichte von Akademie. Akademie und Musik: Erscheinungsweisen und Wirkungen des Akademiegedankens in Kultur-und*

vocabulary acquires an ambiguous meaning. It may refer to a sympathetic affective communication and at the same time to an abstract perfection, inaccessible to the blind instinct for the beautiful. A means of fitting contraries into a congruous relationship, harmony establishes a mathematical bridge between the two extremes of the universe, intertwined in the woof of numerical correspondences between the disembodied reality of cosmic music and its reification in audible phenomena. Idea and sensation, mixed in correct dosages in the crucible of the universe, get fused in a concept of polyphony as animal spirit, which participates in the nature of the sonorous phenomenon as well as in the nature of thought and affection.

Ficinian counterpoint, then, is the deliberated reflection of a psychic power that migrates into song, giving the correct form to the rhythm, the intervals, and the general affection. In its own way, it thinks, narrates, harangues, feels sorry, and laments through its own particular rhetoric, which is very close to that of the four temperaments. This language went along with the conception of artistic criticism as an affective reaction to what is perceived by a faculty intermediate between thought and sensation. When during the 17th century artistic criticism ceased to commune with the theory of the temperaments, in trying to isolate the meaning of music in rhythms and melodies it becomes, evidently, too prolix. Indeed, it is problematic, because it pierces the heart of the most dogmatic triumphs of three centuries of esthetics: the subjective value of the signified, the imposition of a theory of melody, the acknowledgment of personal style as a positive quality, and the idea that music is an ineffable language of tones that have meaning in themselves beyond that of verbal communication and syntax.

Another reason for music history to marginalize Ficino's views of music proper is the belief that he foresaw in his planetary song the accompanied monody of the end of the 16th century. But the analysis of texts shows that the music of which he speaks is a form of polyphony that was very actual, fruit of a compromise between Greek music theory and contemporary counterpoint. As for its practical application, one need only think of the enthusiasm with which Ficino, physician by profession, rates the effective power of music above that of medical therapies.

Musikgeschichte-Institutionen, Veranstaltungen, Schriften. Festschrift für Werner Braun zum 65. Geburtstag (Saarbrücken: Saarbrücker Druckerei, 1993), pp. 11-30.

The strictly quadrivial aspect of the problem, however, remains comparatively unpublished. Allen, one of the most acute expositors, has not hesitated to affirm that the Pythagorean dimension of Ficino's arithmetic has remained "entirely unexplored and perhaps unsuspected by students of Renaissance Neoplatonism;" see Michael J. B. Allen, *Nuptial Arithmetic: Marsilio Ficino's Commentary on the Fatal Number in Book VIII of Plato's Republic* (Berkeley and Los Angeles: University of California Press, 1994), p. 48.

Whoever has inquired into this matter knows that the article of D. P. Walker on Ficino's doctrine of the spiritus remains the only collection of technical facts about it. A perspicacious analysis of texts demonstrates the role of harmonic theory in the mechanics of perception, revealing the justifications for employing a certain genre of melody to neutralize excess melancholy. The goal of his study, however, is not a theory of the affections, rather to establish the nexus between musical harmony and the pneumatology of the spirit. As a result of his altogether legitimate limited focus, Walker avoided seeking in the texts concrete consequences of this pharmacopoeia of the affections. The regime of scales indicated for those among the literary scholars who were most susceptible to the wounds of Saturn remain in a state of simple supposition and do not go beyond fleeting prescriptions furnished by Ficino in *De triplici vita* about the modes to choose on the basis of their character: the Apollonian, Jovial, or Saturnine. However, the general context of Ficino's anecdotal musical therapeutics permits greater precision than that contemplated by Walker.

To evoke a psycho-arithmetic grammar of the affections elaborated by the most representative philosophers of the Renaissance, is not an insignificant accomplishment. Ficino's commentary on the mathematical *loci classici* of the Platonic oeuvre contains for the first time some concrete answers, formulated by a physician expert in both philosophy and ancient music, concerning the psychic power of Greek music, one of the most fertile fantasies of the musical Renaissance.

Expert in her youth in the art of seduction, this Muse was condemned to sleep for twenty centuries by the cryptograms of a not very eloquent musical theorizing. Infused in a compendious form into the cardio-vascular system of the medieval culture of the liberal arts, the blood that animated her states of the soul was crystallized in a clot of remnants of the intelligible canons of a disembodied mathematics, as if they were above and independent of the course of history. Ficino, Medicean musician and physician, is one of the first necromancers of the modern era to have at his disposal the necessary formulas for awakening the mummy of song from her millennial sleep. Asclepius furnished the most precise indications of the method to follow to animate the statues: to insert a demon through a harmonic disposition of members.²

The idea of a spiritual circuit made of harmony and number becomes a reality in the third book of *De triplici vita*, where it transforms counterpoint into an aerial and rational mannequin, devoid of any vital functions of living beings, of humours, or internal sensations. The encounters between this doctrine and ancient and contemporaneous

² "Asclepius," 38, 1-15, in *Corpus Hermeticum*, ed. Jean A. Festugière (Paris: Les Belles Lettres, 1992), p. 349.

musical practice has not received the attention they deserve. Ficino was one of the first to maintain that, just as the imagination of the mother may mould the embryo, the soul manifests itself in everything she does, basing the theory of art as expression on the individual temperament.,

By what paths of communication does the affection insinuate itself under the sonorous surface of counterpoint? What are the characters of the tempered elements of the airy body of melody? What is the informational content conveyed by the spirit to the internal senses? We get an inkling from a passage in the *Theologia platonica* concerning the visions in which the *idolum* communicates to the spirit “the powers of the four elements” tempered by number. But how can we correlate such powers with particular elements of musical grammar?

Harmony as a model for analysis

Ficino’s celebrated definition of counterpoint as a mixture of members articulated in a coherent body contains all the dimensions of the frame that encloses the matter. It supposes a hierarchic conception of the harmonic system that in the theoretical literature governs the general framework of harmonic theory, and in the Neoplatonic environment supplies an extra wheel for the cart that leads the soul to the contemplation of incorporeal reality. The division of sonorous space may be raised from the realm of thought to the level of a model for analysis to dissect the real, as Socrates explicitly affirms in Plato’s *Philebus*, a text abundantly glossed by Ficino. We can take this as a point of departure for delineating an ideal scheme for the pages at my disposal.

A “god”—the legendary Pythagoras—revealed to men the thesis according to which all things are infinite unities and multiplicities.³ The musical tone, which in its raw state constitutes a certain unity, inasmuch as it is a variable quality and tension, is also infinitely multiple. But knowledge of the infinity of tones will not render Protarcus worthy of the title of musician. The connoisseur of music is one who understands the *quantity* and the *quality* of the intervals contained in the high and low registers, the limits (*termini*) and articulations (*compositiones*).⁴ They give access to the text, once the paraphrases are finished, and to various elements of musical theory derived from ancient theory. The word “interval” is interpreted in terms of a consonant excess of one tone over

³ Marsilio Ficino, in *Philebum Platonis, vel De summo bono*, in *Opera omnia*, 2 vols. (Basel: ex officina Henricpetrina, 1576), 2:1235.

⁴ *Ibid.*, p. 1235.

another (*excessus*, *hyperoche*).⁵ The expression “termini intervallorum”—the Latin equivalent of the Greek *horoi*, “boundary term” in the terminology of ancient Pythagoreanism—designates the limits of the *species* or qualities of intervals produced by various types of excesses in the Pythagorean tuning described in the *Timaeus*: the *leimma* (256:243), fourth (4:3), fifth (3:2), octave (2:1), octave-plus-fourth (8:3), octave-plus-fifth (3:1), double octave (4:1). *Compositiones*, which in the Plato’s *Philebus* signify “systems” (*systema*), designates here the articulation of the intervals into “tetrachords, pentachords, and octochords.”⁶ Finally, beyond the species, lies the genus of the same interval in its diatonic, chromatic, and enharmonic variants.⁷

The procedure is dialectic: the dieretic dichotomy of the one into the multiple is to dialectics as the division of unity into submultiples is to harmonic theory.⁸ If the unity of the argument to be examined in its raw

⁵ Ibid. The definition of the interval as an excess between extremes is derived from Philolaus; cf. Philolaus in Porphyry, *Porphyrios Kommentar zur Harmonielehre des Ptolemaios*, 1, ed. Ingemar Düring (Göteborg: Göteborg Högskoles Arsskrift, 1932), 5, pp. 9, 11-15 and *I Presocratici*, 44 A 25, ed. Gabriele Giannantoni (Bari: Laterza, 1986), p. 463, Italian translation of *Die Fragmente der Vorsokratiker*, ed. Hermann Diels and Walther Krantz (Berlin: Weidman, 1961).

⁶ Marsilio Ficino, *The Philebus Commentary*. A critical edition and Translation by Michael J. B. Allen (Berkeley/Los Angeles/London: University of California Press, 1975), p. 267. The observation, more than perspicacious, alludes to the development of the harmonic relation beyond the strait limits of the interval and to the possibility of measuring mathematically the relation between complex elements such as modes, and undoubtedly, the *tonoi*. Theon is silent on this point, but a magnificent development in this sense is the *Harmonics* of Ptolemy, which, in my opinion, Ficino knew. See *infra* and Ptolemy, *Die Harmonielehre*, ed. Ingemar Düring (Göteborg: Göteborg Högskoles Arsskrift, 1930); and *Greek Musical Writings* (=GMW), ed. Andrew Barker, 2 vols. (Cambridge: Cambridge University Press, 1984-1989), 2:331.

⁷ Ficino, *In Philebum*, p. 1235.

⁸ To the point of leading certain authors to the conclusion that Plato had deduced the diaeresis from Pythagorean musical theory; see Paul Kucharski, “Le ‘Philèbe’ et les ‘Éléments harmoniques’ d’Aristoxène,” *Revue philosophique de la France et de l’étranger* 84 (1958): 68 and *passim*; Hermann Koller, “Die Dihäretische Methode,” *Glotta* 39 (1960): 6-24. In projecting the origins of the harmonic system in a mythic past while remaining silent concerning the identify of its creators, the *Philebus* has raised the question of the paternity of such a doctrine, attributable, according to the bipartition of the musical schools recalled in the *Republic* (530d-f), either to the arithmetical orientation of the Pythagorean school, or to the “empirical” direction of the Damonian school. That Plato deduced the diaeresis from musical models is not demonstrable. Leaning on Walter Burkert, *Weisheit und Wissenschaft: Studien zu Pythagoras, Philolaus und Platon* (Nürnberg: Verlag Hans Carl, 1962; trans. Erwin L. Minar, Cambridge, Mass.: Harvard University Press, 1992), p. 78, the “silence” of the Platonic dialogues on this point argues against this hypothesis. Whether Plato’s silence expresses the pro or contra of this question is not evident. That the Pythagoreans of the 5th century are the foundation of Plato’s dialectic is historically absurd. The relation between music and dialectics remains, however, a *locus communis* of academic Pythagoreanism. Ficino certainly must have come across the exegesis of the

state is adopted, knowledge proceeds by dividing the genera and species down to the indivisible, ascertaining the cumulative number of parts; and the process of division continues up to the moment in which the impossibility of specifying further leads the analysis to the presence of the individual species and its correlatives.

Ficino finds these notions in various sources: the ancient scholia to the harmonic generation of the world-soul in Plato's *Timaeus* preserved by Plutarch;⁹ the comments on the *Timaeus* by Proclus and Porphyry, and music-theoretical works the Hellenic period. An influential source, which appears in the allusion to the "systems of four, five, and eight notes," the exposition of Theon of Smyrna, a quadrivial manual of Platonic exegesis that Ficino studies, annotates, and translates for his personal use at the beginning of his philological career.¹⁰ It is a key text, concerning which we can obtain some supplementary details about the semantic density of the concept of harmony. The general texture of melody is a "syntax" of systems (*systematon syntaxis*) "like the Lydian, Phrygian, or Dorian," articulated with differentiated configurations of rising steps of great complexity. High and low pitch are differentiated in the notes, the notes combine into intervals, intervals into systems, systems into *tonoi*, and *tonoi* into organized melody. In addition, melody acquires a linguistic value when the compass of thought, led by the ambiguous signified of the term *logos*—ratio, proportion, discourse—crosses the boundary of musical

Enneads of Plotinus, in which music as a symbol of elevation figures next to love and philosophy. See Plotinus, *Enneads*, I, 3, 1, ed. Giuseppe Faggin (Milan: Rusconi, 1992), p. 87.

⁹ Plutarch, *De animae procreatione in Timaeo*, ed. E. Harold Cherniss (Cambridge, Mass., and London: Harvard University Press, 1976), p. 265.

¹⁰ Theon de Smyrne, *Exposition des connaissances mathématiques utiles pour la lecture de Platon*, ed. J. Dupuis (Paris: 1892; reprint ed., Bruxelles: Culture et Civilization, 1966). Ficino alludes to the translation of the first part in a note to a letter of 6 September 1474 addressed to Angelo Poliziano; see *Marsilio Ficino: Lettere I. Epistolarum familiarium liber I*, ed. Sebastiano Gentile (Florence: L. S. Olschki, 1990), pp. cclix, 44-45 (no. 20). The text, never published, is preserved in Hamburg, Staats- und Universitätsbibliothek, MS. cod. Philol. 305, fols. 139-191^v, as well as in Vatican City, Biblioteca Apostolica Vaticana, MS vat. lat. 4530, fols. 119-51. Concerning the role of Theon in the commentary on the 8th book of the *Republic*, see Allen, *Nuptial Arithmetic*, pp. 31-33. In the manuscripts that contain this version, it is preceded by a vast Latin collection of the mathematical works of Iamblicus, which Ficino must have obtained starting from MS graec. 86.3 and 86.9 of the Biblioteca Medicea-Laurenziana in Florence. See Kristeller, *Supplementum ficinianum*, I, pp. xxx-xxxi, xl-xlii, cxlvi-cxlvii. The manuscript includes the works, *De secta Pythagorica libri quattuor*, *De vita Pythagorica*, the *Protrepticus*, *De communi mathematica scientia*, the commentary on the arithmetic of Nicomachus of Gerasa *In Nichomachi arithmetica introductionem*, or its elements, which in the mind of the author probably constituted the parts of a vast Pythagorean encyclopedia. The translation appears to date from 1464. See Sebastiano Gentile, "Sulle prime traduzioni in greco di Marsilio Ficino," *Rinascimento*, 2nd series, 30 (1990): 57-104.

harmony to include grammar, as Philebus does,¹¹ or metrics, as Cratylus does. The note then is to the interval as the letter is to the long or short syllable. Just as intervals combine into melody, letters are united in syllables, syllables are articulated into words, words into phrases, and phrases into a discourse.¹² Evident in Philolaus' definition of the tetrachord as syllable,¹³ this parallelism may be restored from the venerable tradition of 5th century Pythagoreanism, where the identity between letters and numbers converts melody into the language of numbers. A discourse is logical when arithmetic harmonizes whole numbers, irrational (*alogos*), illogical, and inaudible when the mixture occurs between incommensurable terms. Moreover the ambiguous term "element" (*stoicheion*)—"letter," "number," "note," "segment"—turns music into a physics of contraries.¹⁴ According to the Pythagoreans that Aristotle treats, the system of numbers is a harmony of numerical elements—even and odd—tempered in proper doses in the extremes of intervals.¹⁵ Fifth and fourth, Ficino concludes, are "elements" of the octave ($2:3 \times 3:4 = 1:2$).¹⁶

The circle closes when the root of the term *melodia*—from *melos*, *meleos*, which in Homer means the members and articulations of the arts in living organisms¹⁷—allowing Ficino to transform the union of several

¹¹ Theon, *Expositio*, p. 117. See Ficino, *In Timaeum*, p. 1454.

¹² Theon, *Expositio*, p. 82 (*GMW* 2:213).

¹³ Aristides Quintilianus, *De Musica libri tres*, ed. R. P. Winnington-Ingram (Leipzig: Teubner, 1963), 1.8, p. 15 (*GMW* 2:416); Nicomachus, *Enchiridion*, ed. C. von Jan, *Musici scriptores Graeci* (Leipzig: Teubner, 1895), p. 252, 20 (*GMW* 2:261), Porphyry, *Kommentar*, p. 96, 21; Hippocrates, *Du regime (De diaeta)* I, 8, ed. Robert Joly (Berlin: Akademie Verlag, 1984), p. 132.

¹⁴ Ficino, *In Philebum*, p. 1235. For the sources, see Plato, *Timaeus* 48b-c, *Theaetetus* 202c ff., *Cratylus* 424c. There is a parallel with music and the training of the kitharode in: *Theaetetus* 206b; Aristotle, *Poetics* 1456b. Concerning the musical significance of the term, see Boethius, *De institutione musica*, ed. Gottfried Friedlein (Leipzig: Teubner, 1867, 1.3, p. 189; English trans. Calvin M. Bower, ed. Claude V. Palisca (Music Theory Translation Series; New Haven, Conn.: Yale University Press, 1989), p. 11). On its history: Hermann Diels, *Elementum* (Leipzig: Teubner, 1889); Koller, "Die Dihäretische Methode," pp. 161-174; Johannes Lohmann, *Musiké und Logos. Aufsätze zur griechischen Philosophie und Musiktheorie* (Stuttgart: Musikwissenschaftliche Verlags-Gesellschaft, 1970), pp. 3 ff.

¹⁵ Aristotle, *Metaphysics* 986a 15.

¹⁶ Ficino, *Commentarius in locum Platonis ex octavo libro de Republica de mutatione reipublicae per numerum fatalem*, in *Opera* 2:1416, ed. in Allen, *Nuptial Arithmetic*, III, [iii] 90-91, p. 183: "praeterea duodenarius, sicut intra se duas illas continet harmonias ipsius diapason elementa." The direct source is probably once again Theon, *Exposition*, p. 82 (*GMW* 2:214).

¹⁷ Homer, *Iliad* 7.131; *Odyssey* 11.600; Pindar, *Pythian* 3.48; Aeschylus, *Persae* 991. See Lohmann, *Musiké*, pp. 18-19. An influential source is the Pythagorean fragment of Aristotle preserved in the treatise attributed to Plutarch on music, in which the fixed notes of the Dorian octave are defined as the "corpus of melody" (Ps.-Plutarch, *De la musique (De musica)* 1139b-1140b, ed. François Lasserre (Olten & Lausanne: Urs Graf-Verlag, 1954), p. 122. The Renaissance had access to this through the translation of Valgulo, who,

voices in counterpoint (*concentus*)¹⁸ into a living being endowed with soul and body. The idea of a world as “*liber et scriptura*” written in cryptograms derived by Hermes Trismegistus, Zoroaster, and the god Toth from the heavenly constellations, correspond, then, on the one hand to the thesis of a body as a grammatical system¹⁹ and, on the other, the construction of a musical *physiognomy* of the affections as a key to analysis.

At this point, the method that Ficino implicitly invites us to follow in the analysis of the effective powers of this organism is anatomical. It dismembers the body of a melody into its elementary components and recombines the pieces after subjecting them to a careful analysis of their functions.

not by chance, comments in his Proemium: “*Melos primo significatione membrum corporis dicitur.*” (Melos in its first meaning is defined as a member of the body; see Claude V. Palisca, *The Florentine Camerata: Documentary Studies and Translations* (New Haven and London: Yale University Press, 1989), pp. 23, 35). It is a metaphor diffused also outside musical circles. Leonardo writes: “Dice il musico, che la sua scienza è da essere equiparata a quella del pittore, perché essa compone un corpo di molte membra, del quale lo speculatore contempla tutta la sua grazia in tanti tempi armonici.” (The musician states that his science may be equated with that of the painter, because it comprises a body with many members whose grace the observer contemplates as so many harmonic temporal instances.) See Paola Barocchi, *Scritti d'arte del cinquecento* (Milan/Naples: Ricciardi, 1971-1977), p. 249.

¹⁸ According to Kristeller (“Music and Learning,” p. 271), Ficino neglected polyphony in favor of accompanied monody: “his complete neglect of polyphony and his emphasis on harmony as produced by simultaneous chords might have had some influence on the theories of the Camerata.” Walker also adopts this hypothesis on the grounds of analogies deduced from the summary, in a letter by Poliziano to Pico della Mirandola, of an ode performed as a recitation by a young man in honor of Piero de’ Medici. The equation established between the four voices and the four elements in the commentary on the *Timaeus* (p. 1455), however, demonstrates that the reference in the astral pharmacopoeia of Ficino is to contemporaneous polyphony and not to ancient monophony. The hypothetical anticipation of the ideals of the Camerata is refuted by Ficino’s presumed insistence on the “simultaneous accord of three sounds” as a homogeneous unity reducible to the bass note, of which it is a corollary. Ficino’s *concentus*—the successive harmonies of various voices in counterpoint—ignores the chord, which, instead of causing melody as in Rameau, is a consequence, rather, of the melodic motion of the parts. More than a monochromatic whole reducible to a bass, it is understood as a mixture of various intervals that are equally fundamental. Ficino, for example, is not aware that the minor sixth is an inversion of the major third. See below, the comments on the siderial scale. The last argument in favor of monody is the *lira da braccio* with which Ficino may have accompanied his own Orphic songs. It is a polyphonic instrument, as the contemporaneous repertory of transcriptions for it shows. Thus, as far as Ficino is concerned, “the great war” between “the polyphonists of the North” and the partisans of the humanist taste for the monodic metrical ode in the beginning of the 15th century, imagined by Lowinsky, collapses; see Edward E. Lowinsky, *Music in the Culture of the Renaissance, and Other Essays*, ed. Bonnie J. Blackburn and Ellen T. Harris, 2 vols. (Chicago and London: University of Chicago Press, 1989), 1:171.

¹⁹ Anon., *De physiognomia*, 3.5-13, Förster ed., *Scriptores physiognomonici graeci et latini*, 2 vols. (Stuttgart and Leipzig, 1994), 2:7.

2 *Musica humana*

Ficino's counterpoint imitates the affections and passions, reproducing in our mind the temperament of its composer. A means to understanding his conception of the counterpoint of this living animal, before proceeding to its dissection, is a brief analysis of the psychic powers from which this counterpoint is conceived and perceived. A passage in the *Theologia platonica* authorizes this investigation. There the node psyche-harmony is developed into a system of intervals on the sides of the well-known figure in the form of a lambda, imagined by Crantor, one of the first expositors of the *Timaeus*.²⁰ Thanks to this figure, the progression of the intellect from the universal to the particular may be compared to the diffraction of light by a prism, transparent at the apex, multicolor in the middle, and diaphanous at the base.

2.1 *Mens*

At the head of the soul shines the intellect (*mens*), which "may be compared to the sun;" reason is its light, *phantasia* and the imagination its rays; the shadow of the ideas, *natura*—temperament, or the irrational soul—filters the light, distorting it.²¹ The intellect shares the property of the one, the eye and "head of the soul," which represents with the reason a coherent complex with respect to the fantasy and imagination, destined to a knowledge of superior realities. The intellect sees at a glance what the inferior faculty perceives in several separate images, reassembling the particular qualities that the musician sets in the melody and the temporal development of the musical composition. It loves order and its parts well ordered and uncoloured, dodging the individual stylistic peculiarities. While the sanguinous temperament prefers "the red, the green, and cheerful melodies," the mind creates canonic forms that "please everyone." It approves of the beauty of the circular figure, regular harmony of notes and rhythms.²² It conceives images of ideal women, born with noses that are a synthesis of the best turned out noses, with eyes made up from the most beautiful eyes of all existing women. Similarly it makes a selection of all the stylistic variants of a school and conceives Palestrinian *prima*

²⁰ Ficino, *De rationibus musicae*, p. 52; *Theologia platonica*, XVII, ii, ed. Raymond Marcel (Paris: Les Belles Lettres, 1970), p. 156. According to Plutarch, the figure in the form of a lambda is the fruit of an initiative of Crantor (Plutarch, *De animae procreatione in Timaeo* 1027d, p. 265); it reappears in Macrobius, *Commentary on the Dream of Scipio*, I, vi, 15-18, trans. William H. Stahl (New York: Columbia University Press, 1952), p. 109 and n. 48.

²¹ Ficino, *Theologia platonica*, XIII, ii, p. 210.

²² *Ibid.*, XI, v, p. 128.

prattica counterpoints founded on eternal rules, superior to history and to the particularity of individual tastes.

The mind which suppresses temporal becoming is the antichamber of the memory. Without it, counterpoint—which Ficino imagines as a kaleidoscope of mathematical figures (*schemata*) evolving in time—makes no sense, inasmuch as it assumes a linguistic significance only when the mind perceives the present while remembering the past. Ptolemy and Porphyry had already explained that in “modulation” (*metabole*) the static form (*thesis*) impressed in the memory, persisted, serving the substrate of modifications made to the melody (*metabole*). The confrontation between the acquired form in the memory with the alternation of new forms performed on the melody created an alteration (*alloiosis*) in the fantasy,²³ with pathetic consequences, variable according to the complexity of the established relationship among the elements in the confrontation: the most beautiful modulations are made by passing to the nearest modes, the most dramatic to distant modes.

Besides, memory is an art, as Frances Yates taught in the distant year 1966. It is an art, and even a musical art. A letter of 1458 addressed to someone in the name of “Banco aritmetra” compares the operation of the memory to the action of the digestive system: it assimilates the *intentiones* after having harmonized them with “order,” “proportion,” and “connexion” in a unitary form, like foods cooked by the blood. Therefore, it digests more easily foods rendered more pleasing by a well ordered oration and a sweet song.²⁴ The synthesis, again, is new, but not its sources

²³ Concerning the sources of this doctrine, see Ptolemy, *Die Harmonielehre* 2.6, p. 55, 20 (GMW 2:329ff.) and Porphyry, *Kommentar*, pp. 169, 9ff.

²⁴ There are two drafts of the letter: the first, in Florence, Biblioteca Riccardiana, MS. 146, fol. 114^v. See Kristeller, *Supplementum ficinianum*, 1:39; the second in a printed edition, *Opera*, p. 656: “Adde iis, quod observandum omnino, Aristoteles & Simonides arbitrant, ut certus quidam in ediscendis ordo, vel insit, vel saltem excogitetur, ordo in proportione quadam & connexione consistit... Observandum insuper ut saepe numero quae didicimus, meditemur: sic enim alimenta animi concoquuntur et quasi convertuntur in animum. Confert etiam quam plurimum, si quis eleganti oratione cantuque suavi, quae memoriae mandavit, saepe recenseat. Voluptas enim rerum condimentum est, amoris esca, incitamentum ingenii, voluntatis pabulum roburque memoriae.” (I add to all this that Aristotle and Simonides wish that in the things that we need to learn there be a certain order, whether inherent or imagined, an order that consists in a certain perfection and articulation... It is necessary, moreover, to meditate frequently on the number of what we are memorizing. In this way, indeed, we arrive at the concoction of the nutriments of the soul that are converted in the soul. Particularly effective is to recite with elegant oratory and sweet song what one has learned by heart. Pleasure, in fact, is the seasoning of things, the bait of love, stimulus to genius, nourishment of the will, and the power of memory.) See Patrizia Castelli, “Marsilio Ficino e i luoghi della memoria,” in *Marsilio Ficino e il ritorno di Platone*, ed. Gian Carlo Garfagnini, 2 vols. (Florence: L. Olschki, 1986), 2:383ff. Interesting is the reference by Prof. Castelli (p. 386) to the mnemonic use of the *voces* of the *Dialogo nel quale si ragiona del modo di accrescere et conservar la memoria* of

cited in the letter: the Graeco-Latin tradition, on the one hand, song and music, on the other. If the relationship between music and memory is rare in the *ars*, the nexus of music with memory is fundamental in music theory, thanks to solmization, born of a mnemonic technique in the initial syllables of the hymn “Ut queant laxis, Resonare fibris, Mira gestorum...” The ambiguity between the verbal and sonorous significance of the syllables will serve as a vehicle for the imagination in the *inventio* of subjects “drawn” from the poetic texts. Solmization separates the pitch (*clavis*) of the sound from its value or function in the hexachord (*vox*). Independent of the *materia* of the scale, a hexachordal formula may be manipulated, distorted, and transposed to various regions of the voice, assuming the dual role of a unifying module and vehicle for the form. The most impressive example of this technique is the Mass *la sol fa re mi* of Josquin Desprez, one of the greatest masterpieces of contemporaneous contrapuntal art. The separation between the function of the *voces* and the pitch of the *claves* supposes a process of abstraction of the forms in which it would not be erroneous to recognize a musical *pendant* to the operations of the soul, making the forms independent of the audible impression. The technical term that designates the instrumental transcriptions of this kind of composition is appropriately *fantasia*, and the date of the most precocious examples coincides with the activity of Heinrich Isaac at the court of Lorenzo the Magnificent.

2.2 *Ratio*

Concerning the quantity and qualities of the individual species, reason ascends again to the genre, rediscovering in Plato’s image conveyed by the internal senses a “common idea of humanity.” Reason corrects the things that ought to be corrected, rectifies the form of the intervals distorted by perception, and extracts the causes from the effects.²⁵ This is because reason debates and discusses. Its eloquence assures that, contrary to the mind, it oscillates between one extremity and the other of the soul. It is defined as “the cogitative faculty” (*ratio cogitatrix, opinatrix*) when it

Lodovico Dolce (Venice: Appresso Gio. Battista, et Marchio Sessa Fratelli, 1575), p. 24: “Si come avvenne, che un certo dottore dovendo ridursi in memoria alcune proposizioni, disse a un huom da bene, ecco poste ne’ luoghi le note di Musica: cioè Gamaut, Are, Beni [i.e. Bemi], e le altre che seguono. E nel Gamaut, s’immaginò certo suo amico, il cui nome era Angelo che portava la croce sopra le spalle, così di mano in mano.” (It happened that a certain doctor, having to memorize certain propositions, said to a well-to-do gentleman, place them in the notes of music, namely, Gamma ut, A re, B mi, and those that follow. In Gamma ut, he imagined a certain friend of his whose name was Angelo and who carried a cross on his shoulder, and so forth.)

²⁵ Ficino, *Theologia platonica*, VIII, i, Vol. I, p. 287.

looks down, “intellectual” (*ratio intellectualis*) when it rises to the deduction of the universal. The soul “is irritated, experiences joy and pain” through the “cogitative part,” when the disposition of the body is altered, agitated by the humours. The intellective part, reason, instead, takes note of the dispositions, sometimes consenting, sometimes reacting and dissipating the affections by means of careful meditation.²⁶ From this derives its fundamental liberty. While the *mens* (mind) ties the individual to providence and the *idolum* to the will of astral influences, the *ratio* (reason) obliges the conscience to face the freedom of choice and action.

2.3 *Idolum*

Erratic and confused, Plato’s sonorous imagination penetrates the soul through the spirit, while the corporeal exhalation of the four humours contained in the blood are poised to establish a bridge between the head and the foot of the soul. Afterwards it joins the *idolum*, the seat of the imagination (*imaginatio, sensus communis*) and of the “fantasy,” inferior faculties—messengers of the senses—and the ensemble of the mental faculties. The *idolum* contains the imagination of the mathematical species²⁷ and consequently also the faculty of separating Plato’s modulations of the voice from its corporeal support to imitate and manipulate it in its absence. Thanks to the “fantasy,” the *idolum* analyzes with greater perspicacity the sweetness and intensity of its voice. The *idolum* defines it, however roughly, recreating only the *intentiones* of the soul of the singer and the instrumentalist.²⁸ Stirred by the tumult of the

²⁶ Ibid., XII, ii, Vol. II, p. 212.

²⁷ Ibid., VIII, iv, Vol. I, p. 303.

²⁸ Ficino, *De vita libri tres, quorum primum de studiosorum sanitate tuenda, secundus de vita producenda, tertius de vita coelitus comparanda tractat*, III, 21 (English translation, *Three Books on Life*, ed. Carol V. Kaske and John R. Clark (Binghamton, NY: Medieval and Renaissance Texts and Studies 57, 1989), p. 358: “Memento vero cantum esse imitorem omnium potentissimum. Hic enim intentiones affectionesque animi imitatur et verba, refert quoque gestus motusque et actus hominum atque mores.” (But remember that song is a most powerful imitator of all things. It imitates the intentions and passions of the soul as well as words; it represents also people’s physical gestures, motions and actions as well as their characters.) We should recall that in the language of scholasticism *intentio* means both the application of the mind to an object of knowledge (*intentio formalis*) as well as the object of thought itself, the *obiectum in quod (intentio obiectiva)*. In Ficino’s vocabulary it indicates the incorporeal quality of bodies perceived by the fantasy (*Theologia platonica* XII, iv, p. 170). In *De amore* (M. Ficini, *In convivium Platonis sive de Amore*, ed. Raymond Marcel (Paris: Société d’édition les “Belles Lettres”, 1956) VI, 214), it is love that produces intentions: “Animi amantis intentio in assidua amanti cogitatione tota se versat.” (The intention of the soul of the lover unfolds in the assiduous cogitation of the beloved.) Finally, the reflections on ecstasy in *Theologia platonica* (XII, iv, p. 170)

humours, the fantasy “currit lubrica per similes,” jumps, very speedily makes a rambling speech. From the idea of rain it becomes excited thinking of winds, from winds to the high mountains, from the mountains to the snows.”²⁹ Motivated by a strong concentration, the fantasy can exercise a *virtus immutandi* on the body, that is, to use the vital spirits to alter the surrounding material, communicating affections and infections to the bystanders. Like Cippo, king of Italy, who, after witnessing a bullfight, woke up sporting two horns.³⁰ Or, like that elderly man who passed his fever to a youth whom he hated, piercing him with his own fetid and feverish spirits.³¹

2.4 *Spiritus*

The psychic effect of Greek music occurred in analogous circumstances, thanks to the spirit, which, activated by the impetus of the fantasy, transmits to the soul of the listener the intentions conceived in the internal senses of the musician. More than a suggestive psychological value in the venerable tradition of the fables of the psychic powers of Greek music, the ethos (with the initial eta) was a property of musical objects—from the example of the Sirens, to the episode of Empedocles and Anchitus, in which the mixture of tones in the melody used to placate the murderous anger of a guest is identified with a pharmacist’s compound, the sedative agent mixed by Helen in the wine to prevent the diners from shedding tears.³² To exploit similar powers, the melodic imagination, half sensation, half idea, associated the *virtus immutandi* with the fantasy and required a vehicle, half body, half phantasm, present both in the song and in the airy conduits of the listener, and, if possible, a half-astral body that would allow the establishment of a “mean” between song and the *idolum* of the world-soul (*anima mundi*).³³ A model existed in the Pythagorean equation of the soul with harmony that permitted assigning a psychic faculty to the musical objects and musical properties to the psychic faculties. The Pythagoreans and Aristoxenus, however, made the soul die with the body, which is why the doctrine was limited to the temperament,

prove that the unmeasured attention of thought in the exercise of a determinate activity disperses the intention of the soul, while the peace of the senses augments the limpidity.

²⁹ Ficino, *Theologia platonica*, XIII, ii, p. 216.

³⁰ Heinrich Cornelius Agrippa, *De occulta philosophia libri tres*, ed. V. Perroni Compagni (Leiden: E.J. Brill, 1992) I, lxiv, p. 223.

³¹ Ficino, *Theologia platonica*, XIII, iv, p. 234.

³² Ficino, “Epistolarum liber, I,” *Opera*, p. 651; Iamblicus, *De Vita Pythagorica liber*, 25, 113, ed. L. Deubner (Stuttgart: Teubner, 1975), p. 65; *I Presocratici*, 31A.15, p. 334; concerning the verse sung by Empedocles, see Homer, *Od.*, IV, 221.

³³ Ficino, *In Timaeum*, xxviii, p. 1453; see Ficino, *Three Books on Life*, p. 359.

and the spirit.³⁴ An important point, added by Agrippa to the extracts transcribed from the letter to Ficino, is the idea of a language like the animated *pneuma* (*empsychon*) and accompanied by an act of the imagination, once aired by Aristotle in *De anima* and elaborated by Chalcidius in his *Commentarium in Timaeum* in a context where the divine suffusion—according to Agrippa—becomes the *vox, sonus articulatus*, and *sermonis elementum*.³⁵ The doctrine that he developed on the case, however, he found to hand in the synthesis made by authors such as Sinesius, Macrobius, Proclus, Plotinus, and Porphyry from the Galenic theory of the animal spirits, the *pneuma* of the Stoics, and the magic and hermetic Neoplatonic idea of a vehicle of the soul of an astral nature. The long history of this concept potentially contains a medical physiology of sensation, a theory of the imagination, and a metapsychology of the astral body. It concerns three different aspects preceded by a series of confluences of the osmotic processes between currents not always capable of being reconciled that Ficino is as well able to distinguish as to confound by means of an evasive deployment of terms.³⁶ I limit my investigation to the part of this doctrine that most properly concerns the characters of music.

According to the current Galenic tradition mediated through Albertus Magnus, the spirit is generated when the most subtle part of the blood evaporates under the impulse of the heat of the heart. It contains the powers of the four elements dissolved in the blood. Moved by the contraction and expansion of the heart, it revolves with perpetual motion in the organism.³⁷ It expands and contracts, provoking choler and melancholy, intense or catatonic, “acute” or “grave” passions. Rare or dense, thick or thin, slow or rapid, humid in the brain,³⁸ hot in the heart,

³⁴ Ficino, *Theologia platonica*, VII, x, p. 279.

³⁵ Aristotle, *De anima* 420b (*GMW* 1:79;); Agrippa, *De occulta philosophia*, II, xxv, p. 325; Chalcidius, *In Timaeum*, ed. J. H. Waszink (London: The Warburg Institute, and Leyden: Brill, 1962), 2:220, 256.

³⁶ Paul O. Kristeller, *Il pensiero filosofico di Marsilio Ficino* (Florence: Le Lettere, 1954), pp. 404-405, has shown how on certain points Ficino clearly distinguishes the cosmic vehicle of the soul from its corporal wrapping. Nevertheless on the same page (*Theologia platonica* IX, v, pp. 211-212) the physiological function of this same *spiritus*, distinct from the imagination and the fantasy, is called *currus (ochema)*, according to the technical term consecrated by Sinesius and the Neoplatonists; see Robert Klein, *La forma e l'intelligibile* (Turin: Einaudi, 1975), p. 53.

³⁷ Ficino, *In Timaeum*, p. 1479.

³⁸ Ficino, “Marsili Ficini expositio in interpretatione Prisciani Lydi super Theophrastum,” *Opera* 2:1821 (hereafter *Theophrastus*): “Spiritus est vapor quidam sanguinis sicut sanguis, sic ipse ex quatuor componitur elementis, quamquam longe subtilioribus. Spiritus in corde vitalis evidenter est igneus ex perpetuo cordis motu, efficaciaque et ira...” (The spirit is a certain sanguinous vapor similar to blood, and it is itself composed of the four elements, although far subtler. In the heart the vital spirit is evidently fiery because of the perpetual motion of the heart, its effectiveness and its choler.)

airy in the liver, it radiates to the organs, performing diverse functions,³⁹ among them the action on the internal senses. It communicates to the imagination the powers of the humours with which it comes into contact. When the black bile boils or freezes, it multiplies the speed of operation of the fantasy or produces depression. Subtle, it flies to the brain, where it is employed by the *idolum* as an instrument for analyzing sensations. The soul feels, operating with greater attention when the interior air (*aer inclusus*) present in the ear “oscillates,” altered⁴⁰ in its equilibrium between pairs of contrary qualities. At the point where the contraries meet, the mean must not contain two contrary affective qualities simultaneously. If the spirit of taste were sweet and bitter simultaneously, for example, it would confuse the flavors without discerning either the sweet or the bitter.⁴¹ To the extent that it is a corporeal element, the spirit is subject to generation and corruption; it is fed and regenerated through cathartic remedies, among which the well known astral pharmacopoeia.

Drafted in the years that Ficino translated the *De insomnis* of Sinesius, in the *De vita* he imagines, as is known, an ethereal worldly spirit, independent, as in the human body, of the other faculties of the world soul. The hypothesis of an ethereal pneuma that flows in the veins is Aristotelian. Contained in the virile semen, it transmits the soul of the father to the child, moulding the embryo through its formative power and the imagination of the mother. It determines the quality and the temperament, of the children.⁴² The idea of extending this physiology to the spheres of the celestial vault, however, owes much to the Stoic and Neoplatonic pneumatology. Correlated to a passage in the *Timaeus* (41d-42d) that seemed to lend itself to similar deductions, the idea of a transmitter of heredity becomes a transmitter of the soul, which in the descent through the planetary spheres, thanks to its formative power, reclothes the soul in an ethereal envelope, in which the planets inscribe their own gifts, determining the character and, in part, also the destiny that will weigh on the individual guest. In sleep and in ecstasy, when the corporeal senses are silent, it may wander from one extremity to the other of the world-soul, separating itself from the body, migrating into regions of

³⁹ Vehicle of the formative power that moulds the embryo, it becomes in the testicles the “radical spirit.” It is converted in the liver into the “natural spirit;” a factor in nutrition and formation of blood, it forms in the heart the “vital” spirit (Ficino, *In Timaeum*, p. 1479.) Other definitions in *Theologia platonica*, VII, 6, p. 274; *Three Books on Life*, II, 14-15 and III, 11, p. 302, III, 21, p. 358. For music and poetry, the most important faculty is the spirit of the brain, instrument of exterior sensation and of the imagination and memory.

⁴⁰ Ficino, *Theologia platonica*, VII, vi, p. 276; see St. Augustine, *De musica*, VI, v, 10, ed. Giovanni Marzi (Florence: Sansoni, 1969), p. 521; Plotinus, *Enneads*, III, vi, 2, p. 437; Ficino, *Theophrastus*, p. 1818.

⁴¹ Ficino, *Theophrastus*, p. 1820.

⁴² Aristotle, *De generatione animalium*, 2.3.736b.

the imaginary to witness the visions in which it is a participant or to hear the harmony of the spheres. A secure link ties the *spiritus phantasticus* to music. Plotinus⁴³ did not hesitate to identify “the enigmatic sense of the theory of the harmonic music of the spheres” with the destiny impressed by them on souls during their descent. The link to the imagination is made firmer: the pneumatic envelope is associated with the imagination because it forms a substrate of dreams and visions generated in the ecstasy, when the soul, free from the tumult of the humours, roams in the realms of the imaginary.⁴⁴

Now the idea of a demonic conception of the spirit and some doubts on its role in musical fascination. Tomlinson would have us reconsider the thesis of Walker, accepted by the majority of interpreters, according to which melody unaccompanied by a text can communicate to the inferior faculties indistinct impressions without reaching the superior faculties.⁴⁵ According to this view, Kristeller too was wrong to assign to the spirit the lower rank of a simple passive instrument of sensory perceptions.⁴⁶ Rather, arguments such as the demonic nature of the fantasy established in the commentary on *The Sophist*, the doctrine of rays of Al-Kindi, and a passage of the *Phaedrus* in which the demon of Socrates dictates sounds and melodies, would demonstrate that Ficino conceived his magical songs as demons, as phantasms produced by demonic mechanisms.⁴⁷ The strategy, in short, consists of elevating the semantic content of the spirit of song to the rank of a *pendant* of reason. This hypothesis squares perhaps with the rehabilitation of the fantastic powers undertaken in Ficino’s tracks in 15th century academic circles, through allegorism, symbolism, and the hieroglyphic conception of art and the theory of emblematic devices. Against it stand a series of peremptory affirmations by Ficino on the myopia of the inferior faculties of the soul and as a result reconciles with difficulty with the affirmations on the value of various semantic strata of polyphony.⁴⁸ Granted the elevated mimetic relationship of the commentary

⁴³ *Enneads*, IV, 3.11-12, p. 579.

⁴⁴ Ficino, *Three Books on Life*, I, 2, p. 110. The history of the astral body has been reconstructed by E. R. Dodds, ed., *Proclus: The Elements of Theology* (Oxford: Clarendon Press, 1933), pp. 310-321; see Klein, *La forma*, pp. 53ff; Daniel P. Walker, “The Astral Body in Renaissance Medicine,” *Journal of the Warburg and Courtauld Institute* 21 (1958): 119-133.

⁴⁵ Ficino, *Theologica platonica*, XIII, ii, p. 210: “Atque ut ad vim revertar rationalem, saepe eam aiunt ita se ad mentem habere, ut sermonem ad animam se habere videmus.” (And, to turn to the rational potential, they say that it behaves towards the mind the way that discourse appears to behave towards the soul.)

⁴⁶ Tomlinson, *Music in Renaissance Magic*, p. 106.

⁴⁷ *Ibid.*, p. 125.

⁴⁸ Without the intervention of the reason, the *idolum* does not distinguish clearly sensory impressions, like absent-minded people who do not recognize the identity of acquaintances met on the street: *Theologia platonica*, XIII, ii, p. 211: “Movent saepe

on the *Timaes* among the various semantic colters of counterpoint and the powers of the soul, polyphony acts on the *mens* and on the *ratio cogitativa* through the *significatio* of the words.⁴⁹

Finally, the gist of the question does not concern so much the demonic value of song as the nature of the images elaborated by the sanguinous, imaginative, or ethereal pneuma. It is a matter of establishing whether the commerce of melody with the demonic powers is enough to confer on the information transmitted by the spirit coherent ideas elaborated by the *ratio*. Without language, writes Ficino, “we could live like animals,” because with them we share a fantasy furnished with “a few concepts” sufficient for hunting for food, for the expression of which it is enough to “moo,” “bark,” or “cry out and gesticulate.” To human intelligence, creator of an infinite number of things, instead, is granted the good fortune of

colores aut voces oculos sive aures, confestim visus et auditus suum explent officium, hic videt, ille audit, nondum tamen animus et videre se et audire animadvertit, nisi media nostri potentia sese ad haec intendat. Quod patet in his qui obvios sibi non comprehendunt, dum aliud quippiam attentius cogitant.” (Colors or notes set in motion the eyes and the ears, and immediately the sight and hearing perform their task. The latter sees, the former hears, but the soul is not aware of seeing or hearing without our intermediate power lending its contribution. This happens to those who, thinking with concentration about something else, do not recognize people they meet on the street.)

⁴⁹ Ficino, *In Timaeum*, xxviii, p. 1453: “Adde quod concentus potissimum inter illa quae sentiuntur quasi animatus affectum sensuumque cogitationem animae, sive canentis, sive sonantis, perfert in animos audientes; ideoque in primis cum animo congruit... Concentus autem per aeream naturam in motu positam movet corpus, per purificatum aerem concitat spiritum aereum animae corporisque nodum, per affectum, afficit sensum, simul et animum per significationem agit in mentem... (Add that the counterpoint transmits with great efficacy between the objects of hearing, and as if animated by the affections and cogitations of the soul, whether by the singer or the instrumentalist, in the soul of the listener...)

After having insisted on the fact that the imitation of the instrumentalist (*sive sonantis*) joins to act on the listener with the same vigor as a singer (*sive canentis*), Tomlinson interprets that music acts on the superior faculties of the soul “by virtue of its motion, not its verbal meaning” (p. 114). A lexical analysis, nevertheless, demonstrates that it is the text that acts on the *mens*. Aiming to illustrate the analogy between consonance and soul, Ficino enumerates the powers of the soul touched by the concentus, while the aerial *natura* of song acts on the body, the *aer purificatum* moves the spirit, its *affectus* stimulates the external and internal senses (*sensum simul et animum*), its “signified acts on the mind” (*per significationem agit in mentem*). Or, rather, the term *significatio* designates the words of the song (see *De vita*, in *Opera*, pp. 562-63). The sound of the instrument acts on the affections of the common sense (*affectuum sensuumque*) and on the *cogitationes animae*. This term has a precise meaning in Ficino’s psychology; it indicates the operations of the reason seduced by the *idolum*, its leaning on the particular and affective reactions produced by its confrontation with the sensory impressions (*Theologia platonica*, XIII, ii, ed., p. 212: “Tunc per rationem cogitatricem repente subirascimur quodammodo vel moeremus, vel gaudemus. Ratio intellectualis haec advertit, unde assentitur quandoque, quandoque etiam consiliis et remediis haec fugit et fugat.” (At times we suddenly become angry, we become sad or happy. The intellectual reason notices it, sometimes consents, sometimes chases away the affections through reasons and deliberations.)

language.⁵⁰ When the senses are silent, in sleep and in ecstasy, the *pneuma* may reflect the powers of the celestial *idolum* with the clarity of a crystal decanter. Not so in counterpoint, where the idea is reified in the phenomenon. Not even the soul of the prophet distinguishes the future with clarity. In the annotations that accompany Ficino's translation of Priscianus of Lydia, interpreter of Theophrastus' *De sensu*, the imagination is identified with "Proteus and Chameleon," sea gods of fantastic transformations and animal "versicolor" of a thousand apparitions.⁵¹ The nature of such metamorphoses is revealed by the divinatory mechanics described in the *Theologia platonica*, where the information revealed by the *idolum* of the world-soul generates an Archimboldesque vision of the elements, aquatic animals, juxtaposed paratactically, ignoring genre and species. The powers of the superior *idola* that will cause rain, Ficino explains, represents in anticipation the orbits of the heavens in the forecasting of future rains; the spheres humidify the air; the watery vapor moves the pituitary, the pituitary moves the humid part of the spirit. Just as the spirit is an exhalation of the blood, the blood contains the four humours, and the spirit transmits to the body the powers of the four humours and the four elements. Its watery power excites the enlivened soul through the part that it possesses of the seeds of the watery elements, stirring up the images relative to the pituitary present in the fantasy and wandering in the reason, in such a way that we immediately think of "running water, rain, water-snakes, eels, fish, and the like."⁵² This is because the separate powers move the soul through the body without engaging the reason. From this point of view the power of music poses difficulties analogous to the discussion of astral influence: the eventuality of a *coup d'état* of the spirit in the tribunal of *ratio*, would have deprived the listener of free will, generating holiness or suicides, like in the sailors of Ulysses seduced by the Sirens.

3 *Materia concentus*: *pneuma* and sound.

There remains only to proceed to the anatomy of the paths of communication across which the soul of this organism expresses itself in the body of the counterpoint. The commentary on the *Timaeus* defines

⁵⁰ *Theologia platonica*, XIII, iii, p. 228; counterpoint also imitates gestures and attitudes; see *Three Books on Life*, III, xxi, p. 358; for the text, see above, n. 28.

⁵¹ Ficino, *Theophrastus*, p. 1825; see *Theologia platonica*, XIII, p. 210.

⁵² *Theologia platonica*, XIII, ii, p. 213: "Vis haec suscitatur eas imagines quae in vacante phantasia rationeque sunt ad pituitam pertinentes, ut subito cogitemus flumina, imbres, angues, anguillas, pisces atque similia."

sound as air in motion. What kind of motion is not defined. A more precise indication is in the commentary on the *Philebus*, where high and low pitch arise from the alteration (*alloiosis*), as affections in a substrate of infinite tension. Known to Plato, this concept obtains its definitive formulation in Aristotelian physics, Ficino's model.⁵³ The transformation (*metabole*), let us remember, comprehends the generation *simpliciter* (*genesis kat'ousian*), corruption (*phthora*), and motion (*kinesis*). Movement in the categories of quantity, quality, or location produce respectively increase (*auxesis*), alteration (*alloiosis*) and local motion (*phora*). Generation is distinguished from alteration in that it involves the essence, operating a radical transformation of the support in something fundamentally different. Alteration, instead, has to do with incidental qualities of a passive and invariant substrate that fluctuates in its affective qualities (*pathe*) while persisting in its essence.⁵⁴ Blood is generated by the transformation of the entire seed, but black bile, now cold, now hot, and the tonos, now high, now low in pitch (*kata dynamin*) are altered.⁵⁵

Alongside the physics of the elements, this doctrine involves also acoustics and the analysis of sensory perception, as in the hearing, where the qualities contained in the power of sound alter the airy principle contained in the cavity of the ear, or in the theory of the affections, where it plays a principal role in the identification of the qualities assigned to the elements of musical composition. Tension and relaxation, height and lowness of pitch, in fact, may be understood as the consequence of an alteration of the local motion of the voice, which stops on a note and moves by interval. To the extent that the definition of motion reenters the Aristotelian categories, registers, notes, and intervals may be considered in qualitative terms.⁵⁶ In that case, register is to music as the spectrum of colors is to the visual arts. A simple transposition is enough to transform the character of the modes, "virile" in the authentic, weaker in the plagal. Moreover, the note is to register as color is to the spectrum, while the interval is a "segment" of energy whose character varies as a function of

⁵³ For the first interpretation, see Archytas, after Porphyry, *Kommentar* 56, 5-57, 27, *Presocratici*, 47B.1, pp. 492-493; Plato, *Timaeus* 79-80b; Ps.-Aristotle, *Problems* 11.4, 6 (*GMW* 2:8); Aristotle, *De audibilibus* 803a-f (*GMW* 2:99). For the second, see Aristotle, *De anima* 419b-420b (*GMW* 2:77). Archytas and Plato, let us recall, confuse the categories of volume, vibratory motion, and velocity of propagation. Fast movement produces high pitch, which reaches the hearing more quickly than low pitch. The difference is no clearer even in the definitions of Boethius.

⁵⁴ Aristotle, *De generatione et corruptione* 319b.10, ed. Charles Mugler (Paris: Collection des Universités de France, 1966), p. 18; see 317a.20, pp. 10ff; 328a.23-328, b.22, pp. 42-44; *Categories*, 14b, pp. 277ff, 2a.2-3. The ambiguity transfer/alteration is also Platonic; see *Theaetetus* 181c-d.

⁵⁵ Aristotle, *Metaphysics* 989a.20-25; *De coelo* 3.3.306a ff.

⁵⁶ See Ficino, *De sono*, in Paul O. Kristeller, "The Scholastic Background of Marsilio Ficino," *Traditio* 2 (1944): 302.

the quantity of motion comprehended in its extremes steps: a large one signifies magnanimity, force, anger, and arrogance; a small one weakness and tears.

The hypothesis of a qualitative interpretation of register finds confirmation in a passage in the commentary on the *Timaeus* in which, with the caution “quasi,” Ficino does not hesitate to transfer the quality of the four elements to the four voices of counterpoint.

In the same way that the most expert physicians mix together certain liquids in a certain proportion such that several diverse materials are compounded into a new and coherent form, with the result that besides the elementary power there is also a celestial power,... the most artful musicians temper the low notes as if they were cold stuff, very high notes as if hot stuff, moderately low notes as if humid stuff, and moderately high notes as if dry stuff, in such proportion that a single form is created out of several forms, to which besides the vocal power there ensues a celestial quality.⁵⁷

⁵⁷ Ficino, *In Timaeum*, xxxi, p. 1455: “Quemadmodum medici peritissimi certos invicem succos certa quadam ratione commiscent per quam in unam novamque formam plures atque diversae materiae coeant, et ultra vim elementalem virtutem quoque coelestem mirifice nanciscantur, quod in Mithridatis confectione et Andromachi Theriaca est manifestum: similiter artificiosissimi Musici gravissimas voces quasi materias frigidas, voces item acutissimas quasi calidas, rursus mediocriter graves ut humidus mediocriter, et acutas ut siccas, tanta ratione contemperant, ut unam quaedam forma [sic] fiat ex pluribus, quae ultra vocalem virtutem consequatur insuper et coelestem.”

The confusion between contrapuntal texture becomes a commonplace destined for a brilliant future in the theoretical literature of the 16th century. “La onde,” writes Zarlino in *Le Istitutioni harmoniche* (Venice: [Francesco de Franceschi], 1558), II, 58, pp. 238-39,) “la parte più grave nominano Basso, il quale attribuiremo allo Elemento della Terra.” (For this reason they call the lowest part “bass,” to which we will attribute the element of earth.) To this qualitative conception of registers much is owed also by the metaphor of Mei of the psychic equilibrium of a column kept erect by four opposing ropes. See the Letter of 5 May 1572 in Claude V. Palisca, *Girolamo Mei (1519-1594): Letters on Ancient and Modern Music to Vincenzo Galilei and Giovanni Bardi*. Musicological Studies and Documents, 3 (Rome: American Institute of Musicology, 1960; 2nd, corrected edition, with Addenda, Rome: American Institute of Musicology, 1977), pp. 97, 91, 93; and the paraphrase by Vincenzo Galilei, *Dialogo della musica antica, et della moderna* (Florence: Marescotti, 1581), p. 82. Mersenne, *Questions inouyes* (Paris: chez Jacques Vallery, 1634; reprint ed., Paris: Fayard, 1985), p. 153, reveals the source: “Diodore dit que Mercure avoit eu esgard aux trois saisons de l’année, qu’il rapporta aux trois tons de musique, Acutum ab aestate, gravem ab hyeme, medium, a vere desumens. On n’y eut pas plutost ajouté la quatriesme, qu’on en fit le Tetracorde des Elemens, la basse ayant son raport à la terre, le tenor à l’eau, le hautecontre, ou contratenor à l’air, le dessus au feu.” (Diodorus says that Mercury was thinking of the three seasons of the year, which he related to the three registers of music, the high to summer, the low to winter, the intermediate to spring. One should perhaps have added the fourth [autumn], which would have completed the tetrachord of the elements, the bass being related to earth, the tenor to water, the alto or contratenor to air, and the soprano to fire.) Nothing prevents us from believing that the passage from the trifold system (described in Ficino, *De musica*, p. 651) to “the tetrachord of the elements:” is the fruit of a

The bass register corresponds to earth, the tenor's to water, the alto's to air, and the soprano's to fire. The bass is sluggish and slow like melancholy, the tenor humid and cold like the phlegmatic affections, the alto moderately hot like sanguinous affections, and the cantus hold and dry like *cholera*. The idea of a temperature of sound is not new; it goes back to the origins of pre-Socratic physics. The various degrees of density of the air form in Anaximenes ice, stones, water, vapor, and fire. Sound is, then, a parenthesis between water and fire enclosed between two differentiated grades of density of the air. In a passage of *Naturales quaestiones* Seneca puts in the mouth of Anaximander the thesis that thunder does not produce lightning when "a wind that is too weak does not succeed in resolving itself into flame but only into sound."⁵⁸ Like air, sound is dense or rare, rapid or slow, hot or cold, dry or humid.

The novelty is in the synthesis and in the application to polyphony, of which none of the Greek authors, obviously, ever spoke, at least in these terms. Antiquity, besides, is anything but unanimous on the manner of combining register, density, velocity, volume, and temperature. Ideally, a high sound is rapid, hot, and dense, and a low sound is sluggish, slow, cold, and rare. Density, however, is a property of ice, and rarefaction belongs to fire. The philosopher Anaximenes holds that the "thin breath of air compressed by the lips" gets colder, while the breath "that emanates from an open mouth" gets warmer through rarefaction.⁵⁹ An analogous thesis, with some modification, is in the Aristotelian treatise, *The Generation of Animals*. Animals have a high voice when they move little air with speed. When hot and dense, the breath produces low voices; cold and rare sounds are high. In auloi too, those who play them with a warmer breath and emit sounds like "ah, ah" (*aiazontes*) sound a lower tone.⁶⁰ The author of the *Problems* of Aristotle also discusses this possibility.⁶¹ Ficino, physician and naturalist, follows these opinions assiduously and fundamentally revises them to recombine the relationships carefully. Saturn, sluggish and slow, completes its own revolution in thirty years,

personal initiative of Ficino. That it is not a question of an ancient idea is obvious, inasmuch as it implies polyphony, extraneous to Greek musical theory.

⁵⁸ Anaximander, after Seneca, *Naturales quaestiones* 2.18; *Presocratici*, 12A.23, p. 104.

⁵⁹ Anaximenes, after Plutarch, *De primo frigido*, 7, pp. 947ff; *Presocratici*, 13B.1, p. 113.

⁶⁰ Aristotle, *De generatione animalium* 788a.15-20. The allusion to the pronunciation of sounds in the aulos is interesting, common also in the Renaissance tutors on wind instruments. The allusion occurs elsewhere too; see Ps.-Aristotle, *Problems* 11.13.

⁶¹ Ps.-Aristotle, *Problems* 11.3, 6, 11, 13, 14-16, 19-21, 23, 32, 34, 52 (*GMW* 2:85-91), Aristides Quintilianus, *De musica* 2.14.10-12, p. 81 (*GMW* 2:484). On the *fortuna* of the *Problems* in the Renaissance, cf. Claude V. Palisca, *Humanism in Renaissance Musical Thought* (New Haven and London: Yale University Press, 1985), pp. 51-66.

producing cold, dry, low, and lamenting notes. Mars, on the other hand, “speedy, boiling, and vehement” generates high, sharp sounds of a martial character:

We attribute to Saturn slow, low, hoarse, and lamenting tones, to Mars, on the other hand, sounds of contrary quality: high, pungent, and menacing.⁶²

Sound is “acute” in a literal sense. The Greek equivalent *oxy* may describe sounds, acute angles of geometric figures, or “pungent,” sharp, piquant flavors.⁶³ Acute may refer also to fire. The circle closes when the tradition of Plato’s *Timaeus* posts the ulcerating, penetrating power of fire to the account of the pyramidal structure of his “molecules.”

The conception of a psychic action of registers is a logical consequence: the powers of the four elements contained in sound subvert the thermal equilibrium of the spirit determining the affections and mental states: the heat of the acute produces *cholera*; the inertia of the grave melancholy. In this way the ancient testimony of Plato in *Republic* confirms the variable character of excited and relaxed melodies,⁶⁴ the affirmation of the *physiognomy* of the high register of the voice in choleric people,⁶⁵ Ptolemy’s thesis that the same melodic formula acquires a capacity to excite (*dieertikoterón*) in high-pitched tonoi, and a greater calming capacity (*katastaltikoterón*) in the tonoi located in the low-pitched regions, and the Renaissance convention to illustrate mourning and melancholy through counterpoints for four or more low voices. The psychotropic action, besides, involves not only the height of pitch but tone color, which Ficino invests with affective qualities independent of quantity.⁶⁶ The idea of a physiognomy of melody constituted one of the most widespread commonplaces. In the Latin West, nevertheless, few

⁶² Ficino, *Three Books on Life*, III, 21, p. 360.

⁶³ Aristotle, *De anima* 420a (GMW 2:78). Acute and thin sounds in Ps. Aristotle, *Problems* 11.4, 20 (GMW 2:93); *De audibilibus* 803b (GMW 2:106); Theophrastus, after Porphyry, *Kommentar*, pp. 64, 4-19.

⁶⁴ Ficino, *De musica*, p. 651.

⁶⁵ *Scriptores physiognomonici graeci et latini*, p. 25: “Secundum passionem quidem intendens acutam (*oxian*) vocem putabit aliquis oportere ponere iracundi. Indignatus autem et iratus distendere consuevit vocem et acute loquitur, qui autem remissus stat, et remittit vocem et graviter loquitur.” (In considering passion, some have believed it opportune to place someone who elevates the pitch of the voice in the category of irate people. Someone gripped by indignation and *cholera* raises the pitch of the voice when speaking. A person who is depressed, on the other hand, relaxes, speaking in a low pitch.)

⁶⁶ Plato alludes to it in *Timaeus* 67a-c. Timbre depends on homogeneity of motion, not on velocity. Aristotle agrees in *De generatione animalium* 788a.23-27 (GMW 2:83). The voice is hoarse or clear as a function of the continuity or discontinuity produced by the roughness or regularity of the trachea. Concerning density and slowness, see Boethius, *De musica* I.3.23-25, p. 189 (Bower trans., p. 110). For timbre, see Ficino, *Three Books on Life*, p. 360.

authors wrote or maintained that a determinate timbre could assume a determinate character. This reclothing of the surface of the elements of composition with extra-syntactic semantic values anterior to the language of the arithmetical relationships, in which the color of sound holds the position of its logical relation, represents a relatively unwritten model that none of the authors favoring magic, from Agrippa to Giordano Bruno, passing over Giovanni Battista della Porta, have failed to keep in view. Agrippa, in a chapter sewn together out of unacknowledged citations borrowed from Ficino's writings incarnates souls and psychic values in the stuff of sonorous bodies:⁶⁷ the antipathy that opposes the wolf and the lamb continues to operate in the gut used to manufacture strings, rendering impossible their compatibility in instruments. The artistic potentials of this doctrine remain confined in the long term to the theoretical environment of the tradition of the exemplars of the psychotropic power of ancient music. In the second half of the 16th century we find, however, perhaps some not so casual analogies in the coloristic attempts of the Venetian polychoral school, reaching maturation in the mixture of voices and instruments of the concertato medium, or, in opera in the psychological exploitation of tone color.

4 *Forma concentus*

The airy material of song assumes supplementary qualities in its state as "aër fractus ac temperatus," when, that is, the sonorous motion is determined numerically. "Stasis of motion" in terms of sound is a pitch (*tonos*), an indivisible point or numerical unity. Indeterminate air, formed and fragmented by number, thus enters into the discrete quantities about which arithmetical and harmonic theory speculates. The individualization of the qualities proceeds then in the intervals, regressing progressively into the particular with the subdivision of unity into submultiples. Quality and quantity are confused, in fact, in the mathematical relations established by the extreme pitches of intervals, in their genres and species. In physical bodies, quality is independent of quantity; it is preserved while the body is divided and creates an obstacle to qualities' actions. It is not so in music, where quantity exercises an efficacious action on the mind by virtue of "non-extensive qualities" present in the "point, in unity of number and in harmony,"⁶⁸ with the limited and unlimited united in proper doses. Consonance in these conditions is above all a purely arithmetic notion, and

⁶⁷ Agrippa, *De occulta philosophia* II, xxv, p. 324.; see Francesco Giorgi, *De harmonia mundi totius cantica tria* (Venice: B. de Vitali, 1525), III, 12, fol. 13^v; I, 2, 6, fols. 29^v-30^r.

⁶⁸ Ficino, *Theologia platonica*, p. 43; *In Timaeum*, p. 1446.

its valorization may also dispense with sensory verification. The speech of Eriximas in Ficino's *De amore* separates spiritual beauty from number; in the case of sonorous numbers, nevertheless, the quality of the generating ratio that the interval transmutes into the acoustic field, is made to coincide *more geometrico* with the testimony of the hearing. The problem of the psychic value of the Greek modes, already comprehended in the quadrivial tradition among the tasks of the theory of proportions, may be formulated upstream of the empirical reality and resolved at the level of pure qualitative arithmetic.

The axioms of this mathematics that are useful for forecasting the affection of the consonances involve the idea of mixture (*mixis*). Even and odd are mixed⁶⁹ in the elements of musical syntax as temperamental contraries. In the little work dedicated to the solution of the numeric node woven by Plato into the *Republic* concerning the nuptial number, we read that the even and odd are male and female and that they marry mixing themselves up in the consonances.⁷⁰ The Pythagorean arithmology decomposes number into parts. The global quantity of number is the "material." The sum, or the relation between its parts and the whole, is its "form."⁷¹ Plato loves the number 12, because, besides its "roots," 7 and 5, it contains the ratio of the fifth (3:2) multiplied by that of the fourth (4:3), its "elements,"⁷² even and odd (2 and 3), which, tempered in suitable doses, generate the octave, the most perfect of consonances (2:3x3:4=6:12). In addition, the number 12 is divisible by 1, 2, 3, 4, 6, and 12. All the "mixtures" of these factors, including the squares, generate between 1 and 144⁷³ the Pythagorean scale, adapted by the demiurge to the harmonic generation of the world-soul.

Pushing this parallel mixing-blending (*mixis-krasis*) to its ultimate consequences, Ficino's arithmetic explains the variety of characters of the intervals through a principle that, historically, music shares with humoral medicine from their common origins in the fragments of Alcmaeon of Croton: becoming something else in a blending of contraries as a result of the excess of one of the components. Melody changes its proper character when the modulation alters the measurements adapted to the mixture of its members, the part that is the excess obstinately remaining confined within the limits of its own discordance. Individualization of quality and

⁶⁹ Ficino, *Opera* 2:1416; Allen, *Nuptial Arithmetic*, p. 221.

⁷⁰ *Ibid.*, p. 179.

⁷¹ Aristotle's Pythagoreans assert that number is both "material" and "form." When the sum of the factors is less than the number, the number is "imperfect," if it surpasses the number, it is "abundant," and when it is equal, it is "perfect." The number 8, deficient in its parts, signifies a defective condition. See Ficino, in Allen, *Nuptial Arithmetic*, pp. 175-176.

⁷² *Ibid.*, III, 3, p. 183. The immediate source is probably still Theon's *Expositio*, p. 82 (*GMW* 2:214).

⁷³ *Ibid.*, IV, iv, p. 185.

alteration, pathos and dissidence reveal themselves, therefore, as reciprocal conditions: a colorless whole splits into a rainbow, dividing itself into a dichotomy, like the elements of Empedocles, generated under the reign of “the One.” The task of altering the character of the intervals belongs to the deforming power that the indeterminate Dyad communicates to the even, mouthpiece of the ideal numerical realities of mathematical number:

Among all things, Pythagoreans and Platonists considered unity most perfect and most gratifying... They believed, on the other hand, that the most imperfect and troublesome of all things was dissolute multitude,... a multitude, I say, difficult to resolve into unity.⁷⁴

Meanwhile, the principle of identity, derived from the odd, maintains things within the limits of its own form. The Dyad produces excess and defect, redoubles and divides, generates continuity of geometric space through a process analogous to infinite division of a line into aliquot parts. The Pythagorean antecedent of the determinate dyad, before academic mathematics distinguished the ideal numbers and the mathematical numbers, was the Even, corporeal substrate and at the same time efficient cause of all its determinations (*pathe te kai hexeis*). Among the numerical speculations contained in the fragments of Aristotle’s lost treatise are reckoned the thesis according to which, while the middle term of an even number determines the middle interval through the arithmetic mean between two extremes ($1:2:3 = 1+\frac{3}{2}$), the outer terms (*horoi*) of an Even number limit an open field “without a leader” divisible infinitely and adapted to a receptacle of an indeterminate number (*aoristos*) of means. Besides, the Odd number is male, while the Even is female: the central defect of the Odd, principle (*arche*) of authority exercised on the extremes, mirrors the abyss that opposes the Even, in which ancient Pythagoreanism recognizes the image of theogonic chaos as an unextinguishable matrix of the universe and the measureless demonic powers. The Even communicates this distorting power to the intervals, alternating the excess

⁷⁴ Ficino, *Epistola de rationibus musicae*, p. 53: “Pythagorici ac Platonici perfectissimum omnium et gratissimum etiam unum ipsum existimant, sequenti vero gradu collocant statum in uno, tertio deinde ipsam in unum restitutionem, quarto denique facilem quandam ad unum regressionem. Contra vero imperfectissimum molestissimumque omnium esse dissolutam multitudinem arbitrantur, secundo vero loco processum in multitudinem, multitudinem inquam ad unum difficile redeuntem.” Ibid., p. 55: “Omnino autem meminisse oportet auditum unitate quidem ubique mulceri, dualitate vero quasi divisione quadam semper offendi. Quamobrem quotiens voces duas maxime discernit ut duas, offenditur maxime. Ubi vero discernit minus, minor ibi offensio.”

in the terms of ratios assigned to the consonances, explaining the distorting evolution towards dissonance.⁷⁵

The consonances are more perfect and simpler when they are generated by the *genus multiplex*, where the larger extreme contains a whole number of times the lesser. They degenerate progressively, however, in the superparticular class of ratios, when, divided by more complex ratios, the excess loses its own power of reconciliation. The integrity of the module is maintained in the octave (2:1), in which the greater extreme exceeds the lesser by one. But it disintegrates, losing a half of its own value in the successive relationship, the fifth (3:2)—“sesquialtera”—where the greater extreme contains the lesser once plus a half of itself ($3:2=1+\frac{1}{2}$). With the increase in the progression ($n+\frac{1}{n}$) the part in excess diminishes in the submultiples: it is worth a third in the fourth ($4:3=1+\frac{1}{3}$), a fourth in the major third ($5:4=1+\frac{1}{4}$), $\frac{1}{80}$ in the syntonic comma ($81:80=1+\frac{1}{80}$). The operation concerns the indeterminate dyad in the degree to which the subdivision of the excess in submultiples recalls the infinite division of a line into aliquot parts.

While the multiplex class of ratios maintains the arithmetical integrity of the unifying excess, the superparticular divides it into an infinity, bordering on the indeterminate. This is demonstrated by the manipulation of the *gnomon* cited by Nicomachus and Theon to demonstrate the Pythagorean identity between the Even and the Indeterminate (*apeiron*). It is a question, let us remember, of disposing groups of pebbles, both even and odd, around the sides of a series of squares (*gnomon*) disposed around the first odd number (1) and the first even (2). While the sum of the odd numbers around the unity produces a series of squares (1, $1+3=4$, $1+3+5=9$; $1+3+5+7=16$; $2\times2=4$; $3\times3=9$; $4\times4=16$.) the addition of even numbers generates a progression of rectangles (*inaequilateros*, *heteromekeis*, *pars altera longiores*) ($2+4=6$; $2+4+6=12$; $2+4+6+8=20$... $6=2\times3$; $12=3\times4$.)

Theon cites the operation as proof that the even—indeterminate and enemy of limits—modulates to the infinite the ratios of the sides, compelling the intervals to “systematically span the limits of their own form.” Alterity and dissidence operate, in fact, as reciprocal conditions: with the increment of the series and the division of the excess, the conflicting opposition of the extremes increases, and the more the interval is complicated, the more it is emarginated from the uncolored universality of the consonant system. Welcomed in the *Epistola de rationibus musicae*, this order of ideas leads to the thesis according to which:

⁷⁵ Plutarch, *De E apud Delphos* 388a-c; Ficino in Allen, *Nuptial Arithmetic*, p. 177. This has to do with numbers “parte altera longiores” of the superparticular class ($n+\frac{1}{n}$).

unity always satisfies the hearing, while duality always offends it, as through division. When it discerns two notes such as two separate entities, we feel a greater wound; where it distinguishes them less, it suffers less.

The numerator of the ratio $11:10=1+\frac{1}{10}$, writes Ficino, surpasses the denominator of $\frac{1}{10}$. The deficiency between this ratio and unity is nine parts, a conspicuous value that, however, decreases when the series nears the initial identity. In fact, the unifying module of a sesquialter ratio ($1+\frac{1}{2}$) requires only one part ($\frac{1}{2}$) to “recompose” unity, while the excess of the octave (1) does not require any complement. Seeing that consonance is unity, the operation confirms the thesis according to which “the biggest consonances are the most perfect.” As demonstrated by the part of the commentary on the *Timaeus* reserved for the evaluation of the characters of the consonances, Ficino recalls this thesis in a vetero-Pythagorean reminiscence preserved in the Hippocratic *Regime*, in a context in which an ample digression on the similarity between musical harmony and culinary art constituted the most compelling invitation to cross the frontier between the mathematical and perceptive planes. The ear, writes the author of the fragment, perceives the fusion of the low and high pitches in consonances as taste does the mixture of flavors. The tongue produces high and low pitches, high and low (*oxy*, *bary*, *ano*, *kato*); it perceives sweetness and harshness; harmonized as it should be, it procures pleasure; unharmonized it produces pain. Monotony, however, bores, and extreme variety disgusts, as in a plate in which a cook would unite an unmeasured quantity of incompatible ingredients. The same is said for melody, where the “notes that are most distant form better harmonies” and the “more varied transformations (*metabolai*) give greater pleasure.”⁷⁶

This thesis proves that the micro-intervals represent the black ink of music: with the division of the excess, the difference between sounds diminishes and with it the quantity of motion imparted to the note in passing from one step to the next. The less the motion, the less energy in the interval; the more the extremes are pressed together, the more an interval assumes the relaxed (*mollis*) and melancholic character of low pitch. In confirmation of this, the thesis set forth in the commentary on the *Timaeus*, that besides the quadruple, the “fraction” of the melodic motion produces very rapid sounds that work a “violent” action on the sense, less than that of the sesquitercian (4:3), generating sluggishness and “torpor.”

For this reason “the philosophers censure the relaxed character of the chromatic genre that proceeds by minor semitones and major semitones.”⁷⁷

⁷⁶ Hippocrates, *Du regime (De diaeta)* I.18, p. 138; Ficino, *In Timaeum*, xxxi, p. 1456.

⁷⁷ Ficino, *In Timaeum*, xxxii, p. 1457: “ultra vero quadruplam progredi vetat gratia melodiae non solum quia ex vehementiori motu fractioneque in sensum provenit violentia... Sed ut citra quadruplam redeamus vetat vitandi torporis gratia infra sesquiterciam saepe

It is a question of a general principle already encountered in the 17th century, when Mersenne compares the motion of micro-intervals to the tiny steps of tots and elderly persons.⁷⁸ With the exception of the fourth, placed, despite its priority in the numerical order, after the two thirds and sixths, condescending to the contemporaneous rules of counterpoint, confirm this order of ideas in the *Epistola de rationibus musicae* and in the commentary on the *Timaeus*. The hypate (*e* 1:1) of the Dorian octave species (*e, f, g, a / b, c, d, e*) is severe, stable, and slow, and marks along with the octave, the most stable consonance. The second (*e-f*, 16:15) “decays” from the first. The third (6:5) rediscovers the spirit and “resurges,” recovering consonance. The fourth (4:3) “cadt a tertia” (falls from the third); it is less dissonant, nevertheless, than the second, inasmuch as it prefigures the triumph of the fifth (3:2), the best consonance after the octave. Beyond the limit of the fifth, the harmonic mean, the intervallic characters repeat in a mirror-like way: the sixth (8:5) is soft (*mollis*), like the third; the seventh (9:5) degenerates from the octave, like the second. After this the periodic cycle of *varietas* (*discrepantia vocum*) joins to fill the octave, mother of all consonances and of all modal species.

In short, the minor intervals turn out to be harsher. Thus the hierarchy of rectangular numbers is confirmed. This doctrine, moreover, reveals an interesting aspect of Ficino’s symbolic universe, where the signs communicate “symphonically,” exchanging the proper semantic substance. The second and third, as we saw, share the same character as the sixth and seventh. The more spontaneous reaction is that of imputing such a symmetry to the theory of inversions—if we may be pardoned the

distendere.” (Melodic grace precludes progressing beyond the quadruple... because the fraction of vehement motion communicates a violent character to the sense... To return to within the limits of the quadrupla, we say, the necessity of avoiding torpor precludes [the melody] from falling too often below the limits of the sesquitertia.”)

⁷⁸ Marin Mersenne, *Harmonie Universelle* (Paris: Sebastien Cramoisy, 1636-1637; reprint ed. 3 vols., Paris: CNRS, 1963), 2, “Des chants,” Prop. xxvi, p. 173: “Les demi-tons et dieses représentent les pleurs et les gémisséments à raison de leurs petits intervalles qui signifient la faiblesse: car les petits intervalles qui se font en montant ou descendant, sont semblables aux enfans, aux vieillards et à ceux qui reviennent d’une longue maladie, qui ne peuvent cheminer à grand pas, et qui font peu de chemin en beaucoup de tems.” (The semitones and dieses represent the tears and moans on account of their minute intervals, which indicate weakness, because the small intervals that we make rising or descending are similar to the steps of infants, elderly people, and those who are recovering from a long illness, who cannot walk with big steps and go only a short way in a lot of time.) The source is the physiognomic tradition (see Anon., *De physiognomia*, 75, *Scriptores physiognomonici graeci et latini*, II, 97): “Qui longis passibus incendunt magnanimi sunt et efficaces; parvi autem et restricti passus inefficaces, parci, parvae mentis sunt, dolorum artifices et obscurae mentis.” (Those who walk with big steps are magnanimous and effective; those who proceed by minute and narrow steps are ineffective, parsimonious, not magnanimous, cause pain, and have dull minds.)

anachronism. In the scale with which we are concerned, nevertheless, the sixth is minor and the seventh major: intervals that have nothing in common either with the major third or with the second. The solution is different: the sixth shares a soft (*mollis*) character with the third, because six is twice three.⁷⁹

The character of the interval in these conditions no longer depends on the quality of the generating ratio, rather on the symbolic significance of its ordinal value in the diatonic scale. Fifth and sixth are venereal because 3 and 2, which are wedded in the “nuptial numbers” 5 and 6, are male and female. The fifth may make up to Venus because of “the nectar attributed by the poem to its number” (*quinque lineae sunt amori*), and the third—born like the harmonic mean from the marriage of the extremes 3 and 2—reverts to Adonis and to Cupid.⁸⁰ The osmosis between the ordinal value and the quality of the ratio, moreover, explains also the “celestial” stability of the octave. Just as there are seven intervals, and *varietas* evolves from periods of seven, the divine protector of the octave is Apollo, premature infant of *seven* months, patron of the kithara of *seven* strings and of the therapeutic value assigned by medicine to the *seven* vowels of the Delphic hymns. The circle closes with the thesis that the octave repeats the character of the first step ($8+1=9$), completing the chorus of the *nine* Muses.

The ordinal value of the interval, finally, explains also the meaning of the notes in the celestial concert. The demiurge has inserted the martial and venereal ethos of the fourth in the sidereal scale to temper the harshness of the second and the softness of the third.⁸¹ The sidereal scale produces an octachord with the seven notes of Terpander’s kithara through a complete diatonic tetrachord and a second complementary defective tetrachord. The internal succession of steps is not specified. It is probably a matter of avoiding contradictions with the tradition in which Saturn is assigned at one time the highest step, at another the lowest. To parry this difficulty, Ficino imagines a symmetrical system. He affirms that, in view of the diurnal motion of the sky, Saturn produces the low hypate (*mi* or *e*) and the

⁷⁹ Ficino, *De rationibus musicae*, p. 52: “Sexta igitur redire videtur ad tertiam, ex qua bis replicata componitur ac lenitate quadam molli tertie maxime congruit.” (The sixth seems to return to the third, out of which it is composed twice replicated, and agrees with the sweetness of the minor third.)

⁸⁰ Ibid, p. 51: “Secundo habetur loco proportio sexquialtera quae diapente ipsam scilicet quinte vocis prope modum perfectam efficit harmoniam, cui quidem numero poeta lyricus Venereum tribuit nectar. Tertio sexquarta, ex qua vocis tertie lenis nascitur harmonia Cupidinem referens et Adonem.” (In second place we have the sesquialter ratio, which generates the harmony of the diapente, that is, of the fifth, to which the lyric poet has attributed a venereal nectar. Then follows as the third step the sesquiquartal, from which is born the soft harmony of the third, which recalls Cupid and Adonis.)

⁸¹ Ibid, p. 51; Ficino, *In Timaeum*, xxxi, p. 1459.

moon the nete an octave higher (*mi'* or *e'*). In consideration of the continuous (diuturnal) motion, the moon is assigned the low step and Saturn the high. Since there are seven steps, the sun is in the middle, and the characters of the Dorian scale are organized symmetrically around the center, the resulting order being practically negligible. The system is original. Contrary to what Tomlinson⁸² tentatively suggests, it does not owe anything to Ramos de Pareja, who arranges eight diatonic steps between the moon and the firmament. Ficino's scale, instead, generates an octave with seven notes between the moon and Saturn (**e**, f, g, **a** / **b**, d', **e'**), following the well known model: the diatonic scale of seven steps attributed by Nicomachus to Philolaos.⁸³ We have other indications concerning celestial harmony in the *Epistola de rationibus musicae* and in the commentary on the *Enneads*, where twelve notes of the diatonic scale correspond to the twelve signs of the zodiac. The first and second produce a dissonance of a second analogous to the interval established by the first and second notes of the Dorian scale; the third produces a third, the fourth a fourth, and the fifth a fifth. At first sight one spontaneously imagines a division of the zodiac into aliquot parts, where the first sign (12:12=360°) produces the fundamental (a), the second (11:12=330°) something similar to a tone, the third (10:12=300°) a minor third, the fourth (9:12=270°) a fourth, and so on. When the sixth is reached through the ordinal value of the intervals, it enters into conflict with the ratio: the seventh sign, which, keeping to the text, should produce a seventh, but generates an octave (a', 6:12=180°), and the eighth the minor tenth (c', 5:12=150°). If the quality of the notes do not have anything in common with the ratio of their sectors, only a last possibility remains: Ficino has limited himself to transfer to the twelve signs the ordinal value of the twelve notes of the diatonic system, transforming the diatonic scale into a ring, like the demiurge of the *Timaeus*. If the analysis is exact, the harmonic circle allows us to join to the list of Ficino's musical sources an important text, the only one in the ancient theoretical tradition to project the diatonic scale into the zodiac by folding it over, namely the treatise of Ptolemy.⁸⁴

⁸² Tomlinson, *Music in Renaissance Magic*, p. 84: "Indeed in the four decades after [Ramos de Pareja's] *Musica practica* was published its doctrines helped give rise to a discourse of natural and celestial magic with music at its heart... Ramos, by the way, seems to have spent part of the 1470s in Ficino's Florence and may even have circulated *Musica practica* in manuscript there."

⁸³ A confirmation of this is the substitution in the commentary on the *Timaeus*, p. 1453, of the trite for the paramese. According to Nicomachus, the trite (i.e. third) was the ancient name that Philolaos gave to the third step from the top (*b*), later paramese, of the disjunct tetrachord. This demonstrates that the upper tetrachord completed the octave by means of three notes. See Nicomachus, *Enchiridion*, p. 253 (GMW 2:261). See Burkert, *Weisheit*, p. 371, in opposition to Chailley.

⁸⁴ Ptolemy, *Harmonics* 3.8.12ff, p. 101 (GMW 2:381).

5 *Affectus mensurabilis*

The ambiguity *mixis/krasis* could not but bring and transfer the mathematical notion of the excess to the harmony of the powers latent in the humours. Alteration and identity govern the spirit, a transmitter “ratione quadam harmonica temperatus,” that contains the fifth, fourth, and octave.⁸⁵ But it is in the commentary on the *Timaeus* that the concept of equal rights (*isonomia*), as a brake imposed on the excrescence of powers, is converted into a harmony of whole numbers:

To maintain health, we may say, the body requires eight parts of blood, four of pituitary, two of yellow bile, and one of black bile [8:4:2:1]. In this way, if by chance the blood becomes hotter and more humid by one degree and perhaps also slightly warmer, yellow bile hotter by three degrees and pituitary more humid by three, then the humours of the pituitary with the heat of the bile will reproduce the temperature of the blood.⁸⁶

A glance at the numerical values assigned to the humours allows us immediately to isolate the requisites that in the temperament, is the equipotent of the “rights.” The four terms form a geometric progression, 8:4:2:1. Contrary to what happens in the superparticular class, the series increases while maintaining the identity of the initial ratio. The ratio is the duple, 2:1, of the multiplex—the most stable—class in which the minor term measures the excess of the major by a fixed number of times. The ratio produces the octave, the most perfect consonance⁸⁷ and the only one to maintain the identity of the initial pitch in its replicates. A series like 1:3:9:27, by contrast, would produce a series of different pitches. The evolution is linear, “direct,” arising from the norm or zero degrees of apathy. Moreover, the octave “contains all the consonances.”

⁸⁵ Ficino, *Epistola de rationibus musicae*, p. 54: “... Platonici in ipsa auditus complexione unum terre collocant gradum, aque vero unum quoque, sed tertiam insuper partem, ignis praeterea unum atque dimidium, aëris denique duos. Hinc ergo vim proportionis sexquitertie, sexquialtere, duple oriri maxime arbitrantur.” (The Platonists allocate within the complex of the hearing one step to earth and another to water, giving, however, to the third part, fire, a step and a half, and to air two. From this, they believe, power is generated through the 4:3, 3:2, and 2:1 ratios.) See also Ficino, *Theoprastus*, p. 1811.

⁸⁶ Ficino, *In Timaeum* II, lxxxvii, p. 1481: “Ad bona corporis habitudinem (ut ita dixerim), octo partes sanguinis necessariae sunt, pituitae quatuor, bilis duae, atrabilis una. Item ut sanguis forte uno fit gradu calidus atque humidus, forte etiam paulo calidior, bilis tribus calida pituita tribus humida; sic enim humor pituitae cum bilis calore temperiem sanguinis referre videtur.”

⁸⁷ *Ibid.*, II, xviii, p. 1454.

The parallel categories of heat and humidity demonstrate this. The expression “temperiem sanguinis referre videtur” signifies that the ratio established by the pituitary’s humidity—three times as humid—with the heat of the bile—three times as hot—is referred to the temperature of the blood. A cursive letter suggests the idea of the ratio between the degrees of the pituitary (3), humidity of the bile (3) and the heat of the blood (8). But the relation 8:3:3 is not consonant. It remains only a last resort, that is, the three parts of bile produce a temperature equal to three times what only one does. In such a case two parts of bile generate six degrees of heat, and four of pituitary twelve. The harmonic relation ensues: 12:8:6 ($12 \cdot 8 / 8 \cdot 6 = 12:6$), which contains the fifth, the fourth, and the octave, conforming with the indications furnished for the spiritus.

This point having been established, Ficino may consider, respecting fully the principles of humoral medicine, the generation of the passions as a series of deviations, more or less important, obtained departing from a point of initial reference—the series 8:4:2:1—considered, indeed, as the natural system, arising from zero degrees of apathy or from the expressive norm, starting from which it is possible to measure all the possible rejects, all the dissonances. The distorting tendency of the temperament, is thus converted into a numerical excrescence, and every affection produced by the preponderance of one of the four humours will correspond to the dissident numerical quantity with respect to the concomitant terms of the series.

The classic example is in *De vita*, in which Ficino did not hesitate to distill the intervals of melancholic temperament, into a new numerical model. The melancholy that favors access to the exceptional states—to recall a doctrine perhaps too well known—is a restless substance that bursts into flame like brandy or chills to an extreme cold, producing in the internal senses ardor, depression, and a rainbow of mixed affections, through a kind of intoxication of knowledge that transforms the most mediocre person into an unpredictable being—stubborn, or endowed with exceptional cognitive powers. When this substance burns, the spirits circulate with great velocity, squeezed by the temperature into narrow winding passages of a system of canals that the earthly constitution has rendered dense and compact. Ardor, however, is ephemeral, like burning straw, so that the heating capability is tempered like the wine of the ancients. From this arises the thesis according to which melancholy will maintain its heat like iron if two parts of black bile correspond to two parts of yellow bile and eight of blood.

That [black bile] is mixed with bile and with blood in such a way as to form out of three bodies a single one composed of a duple proportion of blood with re-

spect to the other two, where there will be eight parts of blood, two of bile, and two of black bile.⁸⁸

That this progression has nothing in common with its necessity of tempering contraries results from evidence of the anomalies of his internal order. The temperament, is a three-part counterpoint that may dispense with the pituitary. Even three humours may be too many. To introduce a supplementary space, Ficino assigns equal parts to yellow bile and black bile. The proportion is not quadruple, 8:2, but rather duple, $8:(2+2)=2:1$ —“dupla sanguinis ab reliqua duo.” Such a formula has little in common with the idea of harmony, for Ficino explicitly attests that two extreme terms deprived of two intermediate terms harmonize only weakly—“minime congruunt.”⁸⁹ This is exactly what happens to the values assigned to the melancholic temperament. For what purpose? The mathematical expression of an inimical temperament of mediocrity of the right dimensions could not be assigned to consonant numerical structures. All the attributes of black humour were referred back to dualistic models: the oscillation between the orbit of Saturn and the center of the earth as a model of concentration, Scylla and Charybdis, the duple proportion, and the ethos itself of Saturn as a “wandering and dissonant star.”⁹⁰ Moreover, it was not a question of describing two quantitatively determined mental states, rather a movement in the category of the quality imparted by

⁸⁸ Ficino, *De vita*, I, v, p. 118. “Non tamen misceatur omnino pituitae, praesertim vel frigidiore, vel miltae, ne frigescat. Sed bili sanguinique adeo misceant ut corpus unum conficiatur ex tribus, dupla sanguinis ad reliqua duo proportione compositum. Ubi octo sanguinis partes, duae bilis, duae iterum atrae bilis portiones existant. Accendatur aliquantulum a duobus illis atrae bilis, accensaue fulgeat non urat, ne quemadmodum solet materia durior, dum fervet nimium, vehementius urat, et concitet: dum vero refrigescit, similiter frigescat ad summum.” (But let it not be mixed only with phlegm, especially the more frigid sort, or much of it, lest it get cold. But let it be so mixed with bile and with blood that one body is made of three humors, compounded in a double proportion of blood to the [sum of the] two others; where there are eight parts blood, let there be two portions of bile and two again of black bile. Let the black bile be kindled a bit from two others, and having being kindled let it smolder but not burn, lest, as harder material characteristically does when it boils too strongly, it should burn too intensely and become agitated. But when it cools off, it similarly should become cold in the extreme.) *Three Books on Life*, p. 113.

⁸⁹ Ficino, *In Timaeum*, xviii, p. 1445: “Esto itaque, ut Poësis canit Empedoclis, contraria inter se elementa. Esto et inter contraria medium: quando contraria et maxime distant et absque medio, minime congruunt... Propterea Plato inter contraria semper media saltem inserit duo...” (Let the elements, as the poem of Empedocles versifies, be mutually contrary, and among contraries, let there be a mean. When two contraries oppose each other without a mean, neither can harmonize except weakly... Therefore Plato always places two means between two extreme contraries...))

⁹⁰ Ficino, “De vita libri tres,” III, xxii, in *Opera*, p. 565: “Contra influxum eius [saturni] hominibus communiter peregrinum et quodammodo dissonum nos armat Iupiter.” (Against this influence of his, generally alien to human beings and in a way dissonant, Jupiter arms us by means of the following...: *Three Books on Life*, III, 22, p. 367.)

fantasy from the variable intensity of the spirit altered by the spikes of temperature of the black bile. Nothing is more logical than to imagine the division of a geometric space into an infinite number of degrees and to consign the idea of a central space to the indeterminate dyad as a geometric function of *varietas*. Set free by its means, melancholy could produce an infinite number of psychic nuances of “diverse affections.”⁹¹

6 *The corpus of melody*

When the corpus of melody grows, the mathematical relation crosses the limit of the interval to govern the more complex structures, from modes to melody. Rather evasive on this point, Ficino’s musical narrative leaves this conclusion to the reader. A precise indication, nevertheless, is in the metaphor, formulated in *De vita*, of song as an airy and rational animal, which provides the counterpoint with a system of phalanxes, arts, members, and conjunct and disjunct articulations, clothed in a nervous system that is a cobweb of numerical relations woven by the *spiritus*:

Now the very matter of song, indeed, is altogether purer and more similar to the heavens than is the matter of medicine. For this too is air, hot or warm, still breathing and somehow living; like an animal, it is composed of certain parts and limbs of its own and not only possesses motion and displays passion but even car-

⁹¹ Ibid., I, v, p. 498: “Quae quidem extremitas ceteribus humoribus non contingit... Mediis vero inter frigus caloremque gradibus infecta varie, affectus producit varios, non aliter quam merum, praecipue potens, bibentibus ad ebrietatem, vel etiam paulo liberius affectus inferre varios solet.” (This extremism does not occur in the other humors. Extremely hot, it produces the extremest boldness, even to ferocity; extremely cold, however, fear and extreme cowardice. Variousy imbued with the intermediate grades between cold and heat, however, it produces various dispositions, just as wine, especially strong wine, characteristically induces various dispositions in those who have imbibed to the point of drunkenness, or even just a little too freely: *Three Books on Life*, p. 118.) In short, melancholy generates a variety of affections, whether in the musical or the visual field. From the standpoint of its chromatic qualities, its character is imagined as a “baroque” pearl with opalescent reflections and is thus understood also in the musical field. See *De vita*, I, vi, p. 498: “Quaeret forte quispiam quale sit corpus illud humoris eiusmodi ex tribus illis humoribus ea, qua diximus, proportionem conflatum. Tale est ferre colore, quale aurum esse videmus, sed aliquantum vergit ad purpuram. Et quando tam naturali calore quam vel corporis, vel animi motu accenditur, ferre non aliter quam ignitum rubensque aurum purpureo mixtum calet et lucet, atque velut iris trahit varios flagrante corde colores.” (One might perhaps ask what it is like—that humoral body composed out of those three humors in the aforementioned proportion. In color, it has much the appearance of gold, but somewhat inclining towards purple. And when it is heated, as much by natural heat as by motions of the body, or of the mind, it burns and shines much like red-hot gold tinged with purple; and it takes on in the burning heart various colors like a rainbow: *Three Books on Life*, I, vi, p. 120.)

ries meaning like a mind, so that it can be said to be a kind of airy and rational animal.⁹²

What is the theoretical significance of this analogy? If the connection is more than simply metaphorical, the allusion to air concerns the spirit of song. Its variable temperature recalls the four voices, the sonorous correlative of the four humours. The allusion to the members, conforming to the Greek root of *melos*—member—cannot but designate the segments of the melody, that is, the fourths and fifths marked by the essential steps of the modes. As we saw, fourth and fifth are elements of the octave, and their species—the cyclic permutation of the intervals produced between their two extremities—are the musical equivalents of the secondary qualities mixed in variable proportions in physical bodies.

Here, then, fully respecting the fundamental laws of the humours, Ficino can explain the affection of a musical composition as a product of the variable mixture of its modal elementary qualities (*commixtio modi*). To the unbalanced psychic states produced in the body by the hegemony of a sinning humour correspond in melody the dramatic contrasts generated by the violent confrontation of the vocal parts; and the harmonic mathematics may prove that the ferocity of the clash is directly proportional to the complexity of the established ratio of these parts.

These elements should suffice to restore the gilding to Ficino's coat of arms in the history of 15th and 16th century music theory. From a vaguely Neokantian view of Ficino's harmonic theory as an object of thinking foreign to contemporaneous musical preoccupations, one may oppose first of all the affirmations of the author of the *Epistola de rationibus musicae*, who demonstrates that Pythagoras reserved the title "absolute musician" for whomever achieved an equal competence in the philosophical as in the practical field,⁹³ putting an end to the Boethian dichotomy between *musicus* and *cantor*.

To the testimony of the author we will add Ficino's profound knowledge of ancient music—paradoxically without rivals in specialized musical circles—joined to a unique convergence of medical, musico-mathematical, and pneumatological knowledge he developed for the exegesis of the Platonic dialogues. This metaphysical depth had notable impact on strictly musical theorists, starting with Gaffurio, who gained

⁹² Ibid., p. 563: "Iam vero materia ipsa concentus purior est admodum coeloque similior quam materia medicinae: est enim aër etiam hic quidem calens, sive tepens, spirans adhuc et quodammodo vivens, suis quibusdam articulis artubusque compositus, sicut animal, nec solum motus ferens affectum praeferens, verum etiam significatum afferens quasi mentem, ut animal quoddam aërium et rationale quodammodo dici possit." *Three Books on Life*, III, xxi, p. 358.

⁹³ Ficino, *De rationibus musicae*, p. 52.

access to the music of Greek antiquity as he made notes on the margins of a folio of Ficino's Plato.

There remains only to ask what drove the extensive studies on the role of "art" in Ficino's thought in the past fifty years to focus on the visual "arts" and iconography, from the work of André Chastel to the monumental *Saturn and Melancholy*.⁹⁴ As we have seen, it is the Pythagorean confusion of temperament, with harmonic theory that governs the analyses of the melancholic humour developed in *De vita*. It is also music, the art of time, daughter of the Muses and of Memory, that demonstrates in the commentary on the *Timaeus* how the static forms of design do not act on the affections with the same vigor as song. Ficino's demiurge does not neglect design and the figurative arts. But when he delights in them, he limits his own activity to the surface of physical bodies. When he sets out to create the soul of the world, he tempers instead the even and odd numbers in the crucible of the universe, generating a cosmos that dances like the world imagined by Plotinus in the *Enneads* which shapes harmonically its own members, wedding space and time.

⁹⁴ André Chastel, *Marsile Ficin et l'art* (Geneva: Libraire Droz, 1975); *Art et humanisme à Florence au temps de Laurent le magnifique* (Paris: Presses Universitaires de France, 1952); Raymond Klibansky, Erwin Panofsky, Fritz Saxl, *Saturn and Melancholy. Studies in the History of Natural Philosophy Religion and Art* (London: Thomas Nelson and Sons Ltd, 1964).

MUSIC IN FRANCIS BACON'S NATURAL PHILOSOPHY*

Penelope M. Gouk

Francis was the first English natural philosopher in the 17th century to outline a proposal for the study of sound and its properties, particularly musical sound. His writing on the subject is found mainly in the second and third centuries of the *Sylva Sylvarum* which, according to William Rawley, he intended to be "a Natural History, as may be fundamental to the erecting and building of a true philosophy."¹ There is also a section on 'sound houses' and description of acoustical experiments in the *New Atlantis*, which was published posthumously at the same time as the *Sylva* in 1626.² These works were to have an enormous influence on later acoustical investigations by natural philosophers in England throughout the 17th century. Many of Bacon's ideas on sound and music are not original, being derived from both ancient and modern sources. In this paper the influence of both Aristotle and Giambattista della Porta in particular will be discussed. Yet Bacon was not only influenced by the writings of earlier natural philosophers on sound and music. He was also affected by developments in musical practice and by the activities of various inventors such as Salomon de Caus and Cornelius Drebbel.³

The early 17th century was a period known as the 'Golden Age' of English music, a time when musical composition and performance was flourishing and when new and improved musical instruments were being introduced into England. The court of James I was a focal point for new musical genres and inventions. At the same time the activities of the philosopher-engineers, skilled in the technology of hydraulics, pneumatics

* From *Francis Bacon. Terminologia e fortuna nel XVII secolo*, Lessico Intellettuale Europeo 33, ed. Marta Fattori (Rome: Edizioni dell'Ateneo, 1984), pp. 139-154.

¹ *The Works of Francis Bacon*, ed. James Spedding, Robert L. Ellis and Douglas D. Heath, 14 vols. (London: Longman and Co., 1857-1874; reprint ed., Stuttgart-Bad Cannstatt: Fromman, 1963), 2:331-680; quotation pp. 335-336. Referred to hereafter as *Sylva*.

² *Works*, 3:125-168; section on 'sound houses' pp. 162-163. The other work which Bacon wrote on sound is the *Historia et inquisitio prima de sono et auditu*, in *Works*, 3:655-680. Most of this is duplicated in the *Sylva*.

³ Rosalie L. Colie, "Cornelius Drebbel and Salomon de Caus: Two Jacobean Models for Solomon's House," *Huntingdon Library Quarterly* 18 (1954-55): 245-260; Richard Patterson, "The Hortus Palatinus at Heidelberg and the Reformation of the World," *Journal of Garden History* 1 (1981): 67-104, 179-202.

and mechanics in the tradition of Hero of Alexandria found expression in elaborate garden and theatre machinery, used to arouse wonder and delight. Hydraulic organs, mechanical musical clocks and devices for imitating birds and voices were being built in the palaces and gardens of the English aristocracy.⁴ These demonstrated man's ability to control the forces of nature, including sound. 's desire to enquire into acoustics thus arose in the context of the enormous expansion of the world of sound which was taking place in England in the early 17th century.

The new departure in 's work was that for the first time in English natural philosophy music was not being discussed purely within the context of mathematical ratios. Bacon was not interested in music as a quadrivial discipline linked to arithmetic, astronomy and geometry by its use of small whole number ratios. Throughout his writings on natural philosophy, Bacon rejects the belief that the universe is constructed according to the ratios of the Pythagorean decad (the numbers 1 to 4 which added together make 10) and suggests that natural philosophers should be enquiring into the physical nature of the universe rather than its mathematical ratios. Thus music is considered by Bacon as a sonorous phenomenon of nature, perceived by the senses, rather than as a branch of mathematical speculation. Here Bacon was following Aristotle, who had also rejected the notion of the harmony of the spheres, the soul as a divine harmony, and other well known elements of the Pythagorean-Platonic system of universal harmony. Yet despite the rejection of these Pythagorean ideas, Bacon's approach towards sound and music still contains many elements which might loosely be termed Neoplatonic, not least because Aristotle himself had similar ideas. Aristotelianism was based on principles of order and proportion in nature. It was not only due to the revival of Neoplatonism in the Renaissance that later natural philosophers thought that music could have powerful ethical and emotional effects and that social and political life should mirror the harmony in nature. Aristotle's *Politics* as much as Plato's *Republic* stresses the ethical role of music in society and its powerful effects.⁵ Like Aristotle, Bacon believed in the ethical power of music, its capacity to affect and change the emotions and to determine behaviour. The power of music and the nature of sound in general must, according to Bacon, be subjected to the investigations of the natural philosopher whose task is to discover all the subtleties of nature. Many of the experiments and observations which are outlined in the *Sylva* are based on Aristotle's *De anima* II, 8, and the pseudo-Aristotelian *Problemata* books XI and XIX which are concerned with music and the voice.

⁴ Roy Strong, *The Renaissance Garden in England* (London: Thames and Hudson, 1979).

⁵ Plato, *Republic*, 376E-377E, 411A-412B, 424B-425B, 522A-C; Aristotle, *Politics*, 1339a-1342b.

Yet moved beyond traditional Aristotelianism in his natural philosophy. He also followed Neoplatonism and the natural magic tradition in his approach to sound. Porta's *Magia naturalis* of 1589 was particularly influential. As a result of this influence, the enquiry into the nature of sound formed part of Bacon's ambitious and utopian plans for harnessing the forces of nature, to manipulate and control it by means of science and technology, for the material benefit of mankind. In the *New Atlantis* where the 'sound houses' of Solomon's House are described, Bacon summarizes the main elements of this enquiry into sound. First, all sounds must be understood, how they are generated and transmitted to the ear. Natural sounds should be imitated in various ways, particularly the songs of birds, the cries of animals and the speech of man which can be reduced to a series of articulate sounds. Musical instruments, which are a mixture of natural materials and human artifice, must be examined to reveal how they produce their musical sounds, and new musical instruments might be invented to demonstrate how different tones and timbres can be created. The nature of musical sound itself, its harmony, and the division of quarter tones should be investigated. Finally, by the observation of various natural phenomena such as the echo and resonance between bodies, instruments should be built which extend the range of hearing, and speaking tubes which carry the voice further over long distances. Instruments of this nature are also mentioned by Porta. Bacon's programme thus involves a complex mixture of observation, imitation and manipulation of nature. It is characteristic of a period when there was widespread fascination in the garden, the grotto and the masque as arenas for the containment and control of nature by the use of art and technology.

It is in the *Sylva*, however, that 's ideas about music in particular are most fully expressed. The second century of the *Sylva* opens with the following statement:

Music, in the practice, hath been well pursued, and in good variety; but in the theory, and especially in the yielding of the causes of the practise, very weakly; being reduced into certain mystical subtilties, of no use and not much truth. We shall, therefore, after our manner, join the contemplative and active part together.⁶

It is the task of the natural philosopher to relate practical music to theoretical music and to enquire into the cause of musical sounds, particularly the nature of musical consonance, thereby making the 'mystical subtilties' redundant. 's approach to music is here stated explicitly: he chose to disregard altogether most current speculative music theory which was based on mathematical ratios and proportion. The relationship between string length

⁶ *Sylva*, experiment 101. Each of the ten centuries has a hundred experiments. All future references to the *Sylva* will be by experiment number only.

and pitch was known since the time of Pythagoras, and the bulk of music theory taught in the universities consisted of the teachings of Boethius' *De musica* in which the Pythagorean ratios and the whole system of harmony was expounded. According to the Pythagorean system, the cause of the pleasing nature of musical consonance was the numbers describing the musical ratios themselves rather than due to any physical foundation of sounding phenomena. Even Zarlino in his *Le Istitutioni Harmoniche* of 1558 maintained that the *senario*, the numbers 1 to 6, were sufficient to account for the pleasing nature of musical consonance.

In his rejection of Pythagorean music theory, was perhaps influenced by certain Italian music theorists, who believed they were following the teachings of Aristoxenus, a contemporary of Aristotle. Aristoxenus' works had recently been translated from Greek into Latin by Antonio Gogava.⁷ Aristoxenus, and also Aristotle, stated that musical intervals are not judged as ratios by the reason but are heard as pleasing or unpleasing sound by the ear. According to this view, the primacy of number over tone is false, since the musician naturally divides the scale by tones and semitones measured by the ear rather than by the mind's appreciation of the string length ratios. Music is regarded as a pleasurable, sensuous entertainment rather than as a path to philosophical understanding. Although the 'new philosophy' of the 16th and 17th centuries is often presented as a renouncement of Aristotelian and scholastic dogma, in the case of music theory it was the revival of Aristotelian and Aristoxenian ideas about the nature of music which provided a number of natural philosophers with a fruitful source of inspiration. In Bacon's case the belief that music should be treated as sound led him to suggest an enquiry into the properties of musical sound which was a new departure in English natural philosophy at the time.

However, it must not be forgotten that the Pythagorean approach to music, concentrating on the ratios of consonance, also received a new lease of life in the same period. was unaware of the discovery of the relationship of pitch to frequency made by Benedetti in the 1560s and rediscovered independently by Beeckman, Galileo and Mersenne in the early 17th century.⁸ This discovery, somewhat inconveniently for those who would

⁷ Antonio Gogava, *Aristoxeni musici antiquissimi... Harmonicorum elementorum libri* (Venice: V. Valgrisis, 1562); Claude V. Palisca, *Girolamo Mei (1519-1594). Letters on ancient and modern music to Vincenzo Galilei and Giovanni Bardi* (American Institute of Musicology, 1960); Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, 1978), pp. 14-33.

⁸ Clifford Truesdell, *The Rational Mechanics of Flexible or Elastic Bodies 1638-1788*, in *Euleri opera omnia*, 2nd series, vol. 11, pt. 2 (Turin: 1960), pp. 15-141, Claude V. Palisca, "Scientific Empiricism in Musical Thought," in *Seventeenth-Century Science and the Arts*, ed. H. H. Rhys (Princeton, NJ: Princeton University Press, 1961), pp. 91-137, now in his *Studies in the History of Italian Music and Music Theory* (Oxford: Clarendon Press, 1994), pp. 200-235.

reject Pythagoreanism outright, demonstrated that musical consonance can be represented by frequency ratios, the same small whole number ratios that apply to string length, only inverted since frequency is inversely proportional to string length. Bacon erred somewhat in his vehement rejection of Pythagorean numbers and the role of mathematics in music theory as well as other branches of natural philosophy. Later followers of Bacon in England were to criticize him for his apparent neglect of mathematics which proved to be such a powerful tool in the development of the new philosophy.

Since condemned the idea that musical consonance is based on numbers, he had to explain the power and effects of music in its role as sound. Music must therefore be incorporated into ideas on the manner of hearing, perception and response to sound. Bacon's theories on sensation and perception are only presented indirectly in the *Sylva*, and it is necessary to turn to some of his other works such as the *De augmentis scientiarum* to obtain a clear picture of his ideas. The subject of sensation and perception and the debate over the emotional versus the intellectual effects of music on the listener form part of a complex medico-religious tradition concerned with the relationship between matter and spirit, body and soul. Classical texts and Christian sources which had attempted to Christianize pagan teachings provided a whole range of attitudes towards the nature of the soul and its connection to the body. These texts were drawn on by Renaissance natural philosophers who were themselves attempting to deal with the same fundamental issues. There is as yet relatively little known about Renaissance attitudes towards sound and music and its effects. Thanks to the work of Professor Walker the ideas of Ficino and later Neoplatonists have been made clear, but there were many different approaches to the question which have yet to be investigated in any detail.⁹ This might be contrasted to the study of optics and theories of light which proliferate in the history of science. At present all that may be said with any degree of confidence is that Bacon's ideas on hearing and perception were not original, but can be seen to resemble ideas of earlier natural philosophers. Professor Walker has demonstrated that Telesio's natural philosophy provided Bacon with ideas on the soul and *spiritus*, while Cardano and Porta influenced his attitude towards the power of the imagination and sympathy between animate and inanimate objects.¹⁰

To himself, however, his ideas about sound, hearing and perception were not scraps of diverse philosophies assembled like a jigsaw puzzle.

⁹ Daniel P. Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute, 1958), esp. pp. 3-39, 230-236.

¹⁰ Ibid., pp. 199-202; see also Daniel P. Walker, "Francis Bacon and *Spiritus*," in *Science, Medicine and Society in the Renaissance*, ed. Allen G. Debus, 2 vols. (London: Heinemann, 1972), 2:121-130.

They formed part of a single, coherent natural philosophy. Sound, the object of the sense of hearing, was only one aspect of his whole grand scheme of nature. The *Sylva* must be placed within the context of Bacon's earlier works which have been the subject of close attention by Graham Rees, who has provided an invaluable account of Bacon's cosmology and its development.¹¹ Bacon's natural philosophy was based on the belief that most natural phenomena can be explained in terms of the action of spirit and tangible matter; a pneumatic, rather than a purely atomistic, theory of matter which would deny the role of spirit in the workings of nature. Sound, the object of the sense of hearing, is only one aspect of this system. Bacon believed that sound is a species; that is an immaterial entity containing all the qualities of the sounding body within itself, carried by the medium to the ear. The concept of species was an essential element of Aristotelian-scholastic natural philosophy. In this sense it is clear that Bacon was conceptually very distant from the mechanical philosophers who believed that sound is purely the impact of motion on the ear, perceived as sound by the listener. According to Bacon, the qualities of sound are found in the species carried to the ear and exist independently of the listener. Yet Bacon's theory is not without ambivalence. Sound, although spiritual and transmitted non-mechanically, is produced by the impact of bodies and accompanied by local motion in the medium. Thus it behaves as though it is corporeal despite its immaterial nature¹². Bacon is extremely vague about the manner in which sound is propagated through air, water, or other soft bodies. He hints that there is a similarity between water waves and the motion of sound, but offers no clear model such as that of the Stoics' 'stone in the pond' because for him motion is different from the species of sound.¹³

It is in 's explanation of the effects of sound on inanimate and animate bodies that the difference between his theories and those of the later mechanical philosophers is made most clear. For Bacon, one of the most important qualities of sound as a spirit is its affinity to *spiritus*, a corporeal substance of an airy, fiery nature infused in all bodies. Bacon believed that

¹¹ See the following articles by Graham Rees, "Francis Bacon's semi-Paracelsian cosmology and the Great Instauration," *Ambix* 22 (1975): 81-101, 161-173; "The fate of Bacon's cosmology in the seventeenth century," *Ambix* 24 (1977): 27-38; "Matter theory: a unifying factor in Bacon's natural philosophy?," *Ambix* 24 (1977): 110-125; "Atomism and "Subtlety" in Francis Bacon's philosophy," *Annals of Science* 37 (1980): 549-571; "An unpublished manuscript by Francis Bacon: *Sylva Sylvarum* and other working notes," *Annals of Science* 38 (1981): 377-412.

¹² *Sylva*, § 125, 136, 213, 268; Rees, "Atomism and "Subtlety," " pp. 552, 563.

¹³ *Sylva*, § 290. For Greek theories of sound see John Isaac Beare, *Greek Theories of Elementary Cognition from Alcmaeon to Aristotle* (Oxford: Clarendon Press, 1906), pp. 92-130; Frederick V. Hunt, *Origins in Acoustics* (New Haven and London: Yale University Press, 1978), pp. 9-42.

inanimate bodies respond to sound and resonate or produce echoes because the species of sound mingles with the pneumatical part of the body, its *spiritus*. Pleasing, regular sounds produce a sympathetic response in a body. Like Telesio, Bacon believed that *spiritus*, present in all bodies, is endowed with the capacity for perception, although the ability to actually feel pleasure or pain, sensation, is particular to animals.¹⁴ Thus sympathy between musical instruments, the phenomenon of resonance, is not purely mechanical, but part of the wider sympathy between *spiritus*, sound, and the substance of the heavens, a sympathy which accounts for astral influences on earthly bodies. Here Bacon's ideas seem to resemble certain Neoplatonic and Paracelsian concepts of natural magic.

The effects of musical sound on the listener also arise from the similarity between the species of sound and the *spiritus*, which in man and animals is the sensitive, material soul located primarily in the brain but operating throughout the body. , like Telesio, distinguished between two souls in man, the rational, incorporeal soul infused by God, and the sensible soul held in common with the animals, the instrument of the rational soul. Bacon's *spiritus* has much in common with the animal spirits of Galenic medical theory, but can also be seen as resembling Ficino's *spiritus*. While Bacon himself nowhere outlines in detail the operation of *spiritus* in man, it is possible to infer it from contemporary accounts of the animal spirits. These were generally thought of as being centered in the brain, flowing through the nervous system to the sense organs and muscles. Their functions were usually limited to sense perception, motor activity and mental operations such as the appetite, common sense and imagination. The animal spirits were also responsible for effecting the passions which lie between sense and reason, and excite physical and emotional changes in the body and mind in response to external stimuli.¹⁵ In the *De augmentis scientiarum* Bacon ascribes the role of imagination to the *spiritus*.¹⁶ There is thus a close connection between music and magic, and the power of music to effect changes on the listener, even though Bacon himself did not approve of the use of magic on the credulous.

With these ideas on *spiritus* taken from the *De augmentis*, it is possible to fill out the details of 's brief comments on hearing and response to music given in the *Sylva*. The species of sound, endowed with all its qualities, travels through the air and enters the ear, which like certain caves or hol-

¹⁴ *Sylva*, § 801, 835; Walker, "Bacon and *Spiritus*," pp. 122-123.

¹⁵ Thomas Wright, *The Passions of the Minde* (London: printed by V. Simmes for W. Burre, 1604), and Robert Burton, *The Anatomy of Melancholy* (Oxford: printed by I. Lichfield and I. Short for H. Cripps, 1621), provide contemporary accounts of the animal spirits and the passions. See also Paul H. Kocher, *Science and Religion in Elizabethan England* (San Marino, Cal.: Huntington Library, 1953).

¹⁶ *Works*, 1:421-837; section on *spiritus*, pp. 604-613.

lows found in nature augment these qualities.¹⁷ Bacon was not interested in, or perhaps not aware of, contemporary anatomical knowledge about the structure of the ear.¹⁸ In any case, he seems to locate the organ of hearing, like Aristotle, in the inbred air of the ear, the *spiritus*. The sound mingles with the *spiritus* in the ear which immediately perceives whether it is pleasurable or painful. Pleasurable sounds, particularly musical ones, are produced by regularity and proportion, and equality of the parts and pores of the sounding body which forces the air into one and the same posture or figure. Harsh sounds are irregular and unpleasing, while too great a sound of any kind is also unpleasing because it can destroy the sense.¹⁹ The species of sound are carried by the *spiritus* to the common sense and thence to the imagination. It is also the *spiritus* which is responsible for effecting emotional changes in the listener, producing passions from pleasurable or painful stimuli. The chief power of music lies in its similarity to *spiritus*, and indeed all things heard by the ear make the strongest impression on the senses. Thus hearing is the main vehicle for the transmission of learning and communication. All these ideas can be seen to lie behind the following passage in the *Sylva*:

It hath been anciently held and observed, that the sense of hearing and the kinds of music have most operation upon manners; as to encourage men and make them warlike; to make them soft and effeminate, to make them grave; to make them light; to make them gentle and inclined to pity, &c. The cause is, for that the sense of hearing striketh the spirits more immediately then the other senses, and more incorporeally than the smelling... but harmony, entering easily, and mingling not at all, and coming with a manifest motion, doth by custom of often affecting the spirits and putting them into one kind of posture, alter not a little the nature of the spirits, even when the object is removed. And therefore we see that tunes and airs, even in their own nature, have in themselves some affinity with the affections: as there be merry tunes, doleful tunes, solemn tunes; inclining men's minds to pity; warlike tunes, &c. So as it is no marvel if they alter the spirits, considering that tunes have a predisposition to the motion of the spirits in themselves. But yet it hath been noted, that though this variety of tunes doth dispose the spirits to variety of passions conform unto them, yet generally music feedeth that disposition of the spirits which it findeth. We see also that several airs and tunes do please several nations and persons, according to the sympathy they have with their spirits.²⁰

¹⁷ *Sylva*, § 263.

¹⁸ An early English work which contains the most up-to-date theories of hearing from Italy is Helkiah Crooke, *Microcosmographia: A Description of the Body of Man* (London: printed by W. Iaggard, 1615), pp. 573-612, 691-701. On early modern theories of hearing, see Adam Politzer, *Geschichte der Ohrenheilkunde*, 2 vols. (Stuttgart: F. Enke, 1907-1913), 1; Alistair C. Crombie, "The Study of the Senses in Renaissance Science," in *Proceedings of the 10th International Congress for the History of Science, Ithaca, NY, 1962* (Paris: 1964), 1:93-117.

¹⁹ *Sylva*, § 101-103, 128, 168.

²⁰ *Sylva*, § 114.

According to Walker, here seems also to be following Campanella's belief that musical consonance is not determined by simple mathematical ratios but by the conformity of musical sounds to a particular kind of spirit.²¹ In Bacon's account of music's effects, the intellectual dimension of music and its effect on the rational soul is entirely ignored.

also ignores the effect of speech and the voice on the listener's rational soul, and instead makes the comparison between music and rhetoric, both being means of swaying the emotions. This is consistent with Bacon's preference for an Aristotelian approach to music as a sounding phenomenon rather than as Platonic ratios judged by the soul. Poetry, rhetoric and music are persuasive arts which exert their moral and ethical effects through the emotions rather than by reason. It must be stressed that the tendency to discuss music in the context of its emotional effects was not a new development in the 17th century, part of the breakdown of the Pythagorean cosmology, but a reinterpretation of a predominantly Aristotelian position by some, but by no means all, natural philosophers. In contrast to Bacon, for example, Kepler maintained the belief that the effects of music are entirely due to its harmony with the abstract, rational soul. In other words, music was treated both as a mathematical, abstract subject and as a sounding phenomenon by natural philosophers in the 17th century, and there was continual disagreement among them.

It is clear then, that many complex and sometimes conflicting traditions underlie 's comments about sound and music in the *Sylva*. The spiritual nature of sound and its connection with *spiritus* in all bodies is a dimension of his thought which must not be overlooked, even while his commitment to observation and experiment might be hailed as modern in approach. Yet it must be admitted that the dominant theme of the second and third centuries is the nature and properties of sound and the experiments which Bacon suggests might be undertaken. These, taken from mainly Aristotelian sources, provided a starting-point for many acoustical investigations during the 17th century in England.²²

The main points of 's acoustical 'programme' can be summarized fairly briefly. He first describes the production and propagation of sound in an entirely Aristotelian manner. Sound is produced by one body striking another and is transmitted through a medium, of which the best is air, although water and other porous bodies, particularly soft ones, will also act

²¹ Walker, *Magic*, pp. 201, 231.

²² Penelope M. Gouk, "The Role of Acoustics and Music Theory in the Scientific Work of Robert Hooke," *Annals of Science* 27 (1980): 573-605; Ea., "Acoustics in the Early Royal Society 1660-1680," *Notes and Records of the Royal Society* 36 (1982): 155-175; Ea., *Music in the Natural Philosophy of the Early Royal Society* (London University Ph. D. Thesis, 1982), pp. 25-124.

as media. Not all bodies will produce sound when percussed, neither do all great motions result in sound. Sounds are most easily produced when the air is pent or enclosed, as in pipes and trumpets. Bacon mentions how different musical instruments rely on air or water to produce their sounds. Unlike light, sound can travel in arched lines and through solid bodies, and travels at a finite speed. Bacon has some idea of 'equality' producing a musical tone, but he does not relate this specifically to the frequency of vibration.²³ The following ideas on sound expressed by Bacon derive from the *Problemata*: the pitch of a sound is determined by the quantity of air moved and the speed of its motion. A large quantity of air moved makes a 'base' sound, a small quantity produces a higher tone. The faster the speed of the motion, the higher the pitch. The strength or loudness of a sound depends on the strength of the percussion.²⁴ All these somewhat inaccurate ideas, based on traditional sources rather than the observation which Bacon ostensibly advocates, were to be corrected by Mersenne in his acoustical experiments of the late 1620s and 1630s. The results of these first appeared in the *Harmonicorum libri* (Paris 1635).²⁵

Other obvious examples of drawing on Aristotelian sources are the following statements on sound: that sound travels further at night than in the day; that sounds are better heard inside a room from the outside than outside from within; that sounds travel in the shape of a sphere but are stronger and travel further in a forward direction from the first local impression of the air. Although the voice is inclined to travel upwards, it is more audible from below than above. Bacon concludes that this apparent contradiction may be because the spiritual species of things visible and audible move better downwards than upwards.²⁶

is not only interested in these basic properties of sound, but more particularly with the 'majoration' of sounds; that is, how they can be made louder or propagated further, in accordance with his plans for the improvement of man's control over the elements. Bacon sees majoration as taking place in five different ways: by enclosure simple, enclosure with dilation, communication, reflexion concurrent, and approach to the sensory.²⁷ It is impossible to give their exact modern equivalents, since present-day acoustics does not fit into such a Baconian framework, but it may be assumed that Bacon was thinking of resonance, and the conduction, amplification and reflection of sounds, both in nature and in musical instruments. Here the desire to improve and manipulate nature in the natural

²³ *Sylva*, § 102-103, 115-117, 133, 201-202, 217.

²⁴ *Ibid.*, § 139, 163-165, 178-179; *Problemata* XI, 901a, 904b.

²⁵ On Mersenne's discoveries, see Truesdell, *Rational Mechanics*, pp. 28-33; Hunt, *Origins in Acoustics*, pp. 82-100.

²⁶ *Sylva*, § 143, 201-206; *Problemata* XI, 899a, 903a-b, 904a.

²⁷ *Sylva*, § 153.

magic tradition is evident. In the *Magia naturalis*, discussing how enclosure increases a sound, Porta mentions the use of a speaking tube, and how an 'ear spectacle' can be built to improve hearing, modelled on the shape of the ears of animals that hear well.²⁸ Both these instruments are referred to in the *Sylva*, and were of recurrent interest to natural philosophers during the 17th century.²⁹ For example, in his marginalia on the *Sylva*, dating from the 1640s, Christopher Wren, Dean of Windsor and father of the more famous Sir Christopher Wren, comments on the 'majoration of sounds' and remarks that 'ear spectacles' are used in Spain and England, and are called otacousticons.³⁰ In 1668 the idea of the otacousticon was brought up at a meeting of the Royal Society. In a subsequent meeting, Robert Hooke, a self-styled Baconian, brought in a number of models of the otacousticon in different materials and they were tested by members for their effectiveness. The speaking tube or trumpet received similar attention. In 1672 Sir Samuel Moreland announced his invention of the *tuba stentorophonica*, or speaking trumpet, which he first developed a year earlier in 1671. The prototypes were built by Simon Beale, royal trumpeter and trumpet maker. These instruments could carry speech over a distance of at least a mile and were recognized as having potential military or naval uses for efficient communication.³¹ Thus later Baconians attempted to utilize the empirical skills of instrument makers for the advancement of natural philosophy.

Other ways of sounds being spread over a greater distance or being made to go in a particular direction given by under the general heading of 'enclosure' are by the concave walls of certain buildings, and in certain natural spots in the country where echoes can be observed. The echo exercised a particular fascination for both Porta and Bacon and for later natural philosophers of the 17th century. Both authors note particular acoustical properties of certain buildings.³² One example of such a building given by Bacon is the whispering place at a church in Gloucester, which as a result of this interest was visited by later natural philosophers and subjected to a series of tests and measurements. Dean Wren inserted a page of manuscript in his copy of the *Sylva* which he entitled "my son Holder's descrip-

²⁸ Giovambattista Della Porta, *Magiae naturalis libri XX* (Naples: Salviani, 1589), pp. 257, 296-297.

²⁹ *Sylva*, § 129, 285.

³⁰ Dean Wren's copy of the *Sylva* is a third edition of 1631. His comment on the otacousticon is on paragraph 285, p. 73. See also Rosalie L. Colie, "Dean Wren's Marginalia and Early Science at Oxford," *Bodleian Library Record* 11 (1960): 541-551.

³¹ Gouk, "Acoustics in the Royal Society," pp. 163-165; on Simon Beale (*fl.* 1660-1680), see Lyndesay G. Langwill, "London Wind Instrument Makers of the Seventeenth and Eighteenth Centuries," *Music Review* 7 (1946): 88-102.

³² Della Porta, *Magiae naturalis*, p. 257; *Sylva*, § 140, 148, 151, 243-250.

tion of the whispering-place at Gloucester.”³³ There is a similar account of the church, with a diagram, in the Register Book of the Royal Society. This was submitted at a meeting of the Society in 1662 by Henry Powle and formed part of a series of experiments and discussions on the reflection of sounds undertaken by some of the more active members of the Royal Society.³⁴

Musical sound, however, is one of the most important dimensions in 's acoustical programme, because it represents the greatest control of man over nature, the harmonization of diverse elements. He remarks that “The Just and Measured *Proportion* of the *Air Percussed*... is one of the greatest Secrets in the Contemplation of Sounds,” and suggests a series of experiments which will reveal the “great Secret of *Numbers*, and *Proportions*” governing musical consonance.³⁵ He implies that nothing is known about musical pitch, although the relationship between string length and pitch had been established since the time of Pythagoras. However, Bacon's idea of using musical instruments themselves to enquire into the nature of consonance was as important new departure for music theory. It could only arise in the context of the enormous increase in the production of musical instruments in this period. As he rightly suspected, instrument makers, organ makers and bell founders in particular were far in advance of natural philosophers in understanding at least empirically the properties of the instruments they made. Some of the secrets of their closely-guarded crafts were becoming known, however. In 1615 Salomon de Caus published *Les raisons des forces mouvantes* in Frankfurt which includes a treatise on the construction of organs and the means by which they were tuned. Perhaps in the light of such knowledge, Bacon suggests a whole series of experiments on the properties of string and wind instruments and also bells, to see how the material used, the shape of the instrument, the length and thickness of the string or pipe, and various other factors determine musical pitch and timbre.³⁶ It does not appear that Bacon himself performed any of these seriously, if at all. Mersenne, however, did undertake just such a project, as the *Harmonicorum libri* and the *Harmonie Universelle*, 2 vols (Paris, 1636-37) reveal.

³³ *Sylva*, p. 148. In Dean Wren's copy of the *Sylva* p. 46 there is an account by him of some 'diligent enquiries' he made on the whispering place. These may have dated from before the *Sylva* was first published, since according to Wren they took place when Dr William Laud (future Archbishop) was 'newly made' Dean of Gloucester, in appointment made in 1616. However William Holder's diagram of the whispering place which is inserted into the book can only date from 1643 when he married Susannah Wren, daughter of Dean Wren.

³⁴ Royal Society Register Book, vol. 1, pp. 197-205; Gouk, *Music in the Natural Philosophy of the Early Royal Society*, pp. 92-97.

³⁵ *Sylva*, § 183.

³⁶ *Ibid.*, § 184-187.

Other experiments that suggests are those to enquire into the nature of sympathy, or resonance in instruments. Here the influence of instrument makers and performers in the Stuart court is particularly evident. In his discussion of sympathy Bacon describes a type of viol fitted with a course of sympathetic strings of wire under those actually played. This instrument has been identified as the lyra viol, invented shortly after 1600 by Daniel Farrant, an English violist and lutenist. Farrant, son of an organist of St. George's Chapel, Windsor, is also credited with the invention of the polyphont, a cittern-type instrument, and an unknown instrument called the stump.³⁷ These stringed instruments were among a number which had been recently introduced in England. Instrument makers were constantly developing and improving their designs at this period. Inventors such as Drebbel were also involved in experimenting with new instruments. Drebbel is credited with the invention of a 'perspective lute' and virginals which played automatically when exposed to sunlight. This latter instrument, along with his models for a perpetual motion machine, was on display at Eltham Palace and an object of much curiosity.³⁸ Bacon himself was obviously familiar with the automatic virginals; in the *Phaenomena Universi* he refers to "certain Hollanders, recently come among us, who have made a certain instrument of music which when struck by the rays of the sun emit soft music."³⁹

In the *Sylva* he refers also to the orpharion and bandora, two less well-known types of cittern, as well as the ordinary lute and viol. He concludes that the lyra-viol was of little use in practical music, but goes on to suggest how the phenomenon of sympathy might be investigated further by the natural philosopher:

The experiment of sympathy may be transferred (perhaps) from instruments of strings to other instruments of sound. As to try, if there were in one steeple two bells of unison, whether the striking of the one would move the other, more than if it were another accord: and so in pipes (if they be of equal bore and sound) whether a little straw or feather would move in the one pipe, when the other is blown at an unison.⁴⁰

³⁷ Francis W. Galpin, *Old English Instruments of Music* (London: Methuen, 1965), pp. 23-24; *New Grove Dictionary of Music and Musicians*, ed. S. Sadie, 20 vols. (London: Macmillan, 1980), 6:405.

³⁸ On the 'perspective lute' see Robert J. W. Evans, *Rudolf II and his World* (London: Clarendon Press, 1973), p. 190. The automatic keyboard was seen by the Prince of Wirtemberg on his visit to Eltham in 1610: William B. Rye, *England as seen by Foreigners* (London: J.R. Smith, 1865), p. 61. An account of the device is also given in John Wilkins, *Mathematical Magick* (London: printed by M. F. for S. Gellibrand, 1648), pp. 148-149.

³⁹ *Works*, 3: 711-712: "Erant etiam Batavi quidam nuper apud nos, qui organum quoddam musicum confecerant, quod radiis solis percussus symphoniam quandam edebat."

⁴⁰ *Sylva*, § 281.

Experiments of sympathetic vibration and overtones continued throughout the 17th century. These were influenced to some extent by . For example, Edmund Chilmead, a scholar of Christ Church, Oxford, and a musician, gave the first correct explanation for overtones in a vibrating string in the early 1640s. This is found in Chilmead's twenty-point discussion of the second and third centuries of the *Sylva*, a manuscript which is now in the Bodleian library.⁴¹ In this work Chilmead attempts to correct what he regarded as the most glaring errors in Bacon's theories on sound, in the light of information in Mersenne's *Harmonicorum libri*. He is at pains to point out, however, that he is not attacking Bacon, but merely attempting to increase understanding of music with the aid of recent research in a manner that Bacon himself would have approved of. Chilmead's attitude towards Bacon's ideas on sound and music is similar to those of later English natural philosophers. The great strength of the *Sylva* is that it provided a suggestive but vague outline of a programme of investigation that could be undertaken by any aspiring Baconian. Dean Wren's observations on the work have already been mentioned, as have some of the early acoustical experiments undertaken by the Royal Society. Robert Plot's observations about the acoustical properties of buildings in Oxford and various natural locations in the area were also inspired by the *Sylva*.⁴² In 1683 Narcissus Marsh, Bishop of Ferns and Leighlin, read a paper to the newly-formed Dublin Philosophical Society entitled *An introductory essay to the doctrine of sounds, containing some proposals for the improval of acoustics*. Apart from the new use of the word 'acoustics,' the contents of this paper are entirely Baconian, and indicate that the desire to improve and harness nature for the benefit of man was as strong as ever in this period.⁴³

Yet there were limitations to 's influence on acoustical enquiry, as Chilmead was one of the first to point out. Bacon's apparent rejection of mathematics and numbers meant that observations would remain unquantifiable. When it came to precise measurement and quantification, actual experiment and demonstrations on sound, the chief source of inspiration for all natural philosophers had to be Mersenne, who was the first to undertake a large-scale enquiry into acoustics in the 17th century. The other limitation of Bacon's works for later natural philosophers was that Bacon still considered sound as a species, an immaterial entity distinct from the motion which accompanied it. It was precisely when the *Sylva* first appeared that the mechanical explanation for sound, that it consisted entirely of matter in motion, was beginning to be adopted by natural philosophers such as

⁴¹ Mordechai Feingold and Penelope M. Gouk, "An Early Critique of Bacon's *Sylva Sylvarum*: Edmund Chilmead's Treatise on Sound," *Annals of Science* 40 (1983): 139-157.

⁴² Robert Plot, *The Natural History of Oxfordshire* (Oxford: 1677), pp. 7-17.

⁴³ Narcissus Marsh, "Introductory Essay," *Philosophical Transactions of the Royal Society of London* 14 (1684): 472-488.

Galileo and Mersenne. The mechanical theory was eventually to become the most widely accepted explanation for sound among English natural philosophers.⁴⁴ Thus while Bacon's ideas for experiments were frequently taken up by natural philosophers, his account of the nature of sound became outdated.

Music, like so many other elements of 's natural philosophy, demonstrates the complexity and ambivalence of his approach to knowledge. While he advocated experiment and observation using the resources of musical instruments and the skills of craftsmen, Bacon in fact relied almost entirely on traditional Aristotelian sources for his account of sound. Although he rejected the number symbolism of Pythagoreanism, his belief in the power of music to affect behaviour and to arouse the passions was part of a continuing tradition based on the Platonic concept of harmony and proportion, the essential unity of nature. Bacon's desire to investigate the properties of sound was not simply a disinterested pursuit of truth; it was an essential element of his ambitious scheme to dominate and control the forces of nature and the elements, to tame them for the service of man. In this sense music for Bacon was not merely a sensuous entertainment; it was an integral part of natural philosophy.

⁴⁴ Gouk, *Music in the Natural Philosophy*, pp. 25-73.

Music in Francis 's Natural Philosophy: Postscript

Having been given the opportunity to revise a paper first written some fifteen years ago, I have decided to summarize the changes I would now make to my argument in a postscript. This addendum, based on material in Chapters 3 and 5 of my book on *Music, Science and Natural Magic in Seventeenth-Century England* (Yale, forthcoming), draws attention to recent historiography in the field, as well as showing how my own understanding of the role that music played in 's natural philosophy has developed since 1984. In brief, there are two arguments in this paper which I would now formulate quite differently: the first concerns Bacon's attitude towards mathematics, while the second addresses the supposed contrast between his ideas about the nature of sound and those of later mechanical philosophers. Both these issues can be better understood through a more detailed study of the position of music in Bacon's system of philosophical knowledge.

Looked at as a whole, it is clear that 's system adopts a thoroughly Aristotelian stance on both the art and science of music, a position informed by the most recent developments in Italian philosophy.¹ Located under the broad heading of human philosophy (ethics), practical music is considered one of the 'voluptuary arts' because of its immediate effect on the passions. Bacon's emphasis on music as a powerful communicative art follows a well-established humanist tradition and resembles Patrizi's treatment of music as an essential part of poetics.² Bacon also takes a neo-Aristotelian line in his treatment of speculative music (i.e. systematic theories of the nature and causes of musical sound), a position which accounts for his seemingly ambivalent attitude towards mathematics.³

Within the scholastic tradition enshrined in the university curriculum, music was treated as a mathematical discipline, and was taught according to the Pythagorean principles expounded in Boethius's *De musica*.⁴ This approach not only assumes that mathematics is hierarchically superior to physics, but also that 'true' music is found in arithmetical ratios rather than the immediate sensuous experience of live performance. In keeping with his emphasis on experiential rather than abstract knowledge, adopted the Aristotelian conception of the mixed sciences (*scientiae mediae*). These disciplines, which apart from music (harmonics) also included optics, mechanics and astronomy, used mathematical principles to study certain areas susceptible to mathematical consideration. In contrast to the quad-

¹ For further discussion of new philosophical approaches to Aristotle, see *The Cambridge History of Renaissance Philosophy*, ed. Charles B. Schmitt, Quentin Skinner and Jill Kraye (Cambridge: Cambridge University Press, 1988), esp. Alfonso Ingegno, "The New Philosophy of Nature," pp. 236-263.

² Claude V. Palisca, *Humanism in Italian Renaissance Musical Thought* (New Haven and London: Yale University Press, 1985), esp. pp. 369-407; Ann E. Moyer, *Musica Scientia. Musical Scholarship in the Italian Renaissance* (Ithaca and London: Cornell University Press, 1992), esp. pp. 235-241.

³ For further discussion of musical science in general during this period, see H. Floris Cohen, *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht: D. Reidel, 1984).

⁴ Anicius Manlius Severinus Boethius, *Fundamentals of Music*, trans. with introduction and notes by Calvin M. Bower, ed. by Claude V. Palisca (New Haven and London: Yale University Press, 1989).

rival disciplines of Boethius, these mixed sciences could be regarded as a hand-maid to natural philosophy rather than a higher and independent form of truth.⁵

The principal division that identifies in natural philosophy is between its practical and speculative branches. The speculative side (further divided into physics and methaphysics), is concerned with underlying causes and explanations for particular phenomena, including musical sound. As we have already seen, Bacon relied heavily on Aristotle and other peripatetic sources in his analysis of musical sound in the *Sylva*.⁶ The operational side of natural philosophy, concerned with 'enlarging the bounds of the human empire,' is correspondingly divided into mechanics and magic, both of which are concerned with the production of marvellous effects.⁷ The new 'Acoustique art' Bacon alluded to in his *Advancement of Learning* (1605) was clearly based on experimental work described by courtly engineers and natural magicians like De Caus and Della Porta.⁸ Musical technology proved to be one of the most fruitful areas for Bacon's programme of investigation, which by its very nature excluded number as a causal explanation for musical phenomena.⁹

The other most important change in my thinking is that I would no longer claim that later English philosophers rejected 's vitalistic conception of *spiritus* in their mechanistic explanations of the production and perception of musical sound.¹⁰ The prevailing consensus among historians of science at the time I wrote my dissertation was that the rise of the mechanical philosophy inevitably entailed the decline of a magical, animistic worldview.¹¹ More recent studies have indicated a considerable degree of overlap between these supposedly incommensurable positions. John Henry in particular has shown how many English philosophers

⁵ Michael S. Mahoney, "Infinitesimals and Transcendant Relations: The Mathematics of Motion in the late Seventeenth Century," in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert S. Westman (Cambridge: Cambridge University Press, 1990), pp. 461-491.

⁶ For a recent English translation and commentary on this materia, see Andrew Barker, *Greek Musical Writings Volume II: Harmonic and Acoustical Theory* (Cambridge: Cambridge University Press, 1989). On Greek and medieval theories of hearing, see *The Second Sense: Studies in Hearing and Musical Judgement from Antiquity to the Seventeenth Century*, ed. Charles Burnett, Michael Fend, and Penelope Gouk (London: The Warburg Institute, 1991).

⁷ For further discussion of mechanics and magic, see William Eamon, "Technology as Magic in the late Middle Ages and the Renaissance," *Janus* 70 (1983): 171-212; Nicholas L. Clulee, *John Dee's Natural Philosophy: Between Science and Religion* (London: Routledge & Kegan Paul, 1988); Penelope M. Gouk, "Natural Philosophy and Natural Magic," in *Rudolf II and Prague: The Court and the City*, ed. Elizabeth Fuciková (London: Thames and Hudson/Skira, 1997), pp. 231-238.

⁸ On Della Porta and natural magic, see William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton: Princeton University Press, 1994).

⁹ For further details of this technology, see Peter Holman, *Four and Twenty Fiddlers: The Violin at English Court 1540-1690* (Oxford: Clarendon Press, 1993).

¹⁰ Penelope M. Gouk, "Some English Theories of Hearing in the Seventeenth Century: before and after Descartes," in *The Second Sense*, pp. 95-113.

¹¹ Brian Vickers, ed., *Occult and Scientific Mentalities in the Renaissance* (Cambridge: Cambridge University Press, 1984).

were reluctant to adopt Descartes's strict dualism, and instead postulated a hierarchy of matter ranging from the most passive at one extreme to the most active at the other.¹² Robert Frank's detailed investigations into physiology and pneumatics during this period also suggests that Bacon's conception of *spiritus* as the first instrument of the soul had a direct influence on Thomas Willis and other medical theorists of the time.¹³

¹² John Henry, "Occult Qualities in the Experimental Philosophy: Active Principles in Pre-Newtonian Matter Theory," *History of Science* 24 (1986): 335-381; see, also, Penelope M. Gouk, "The Role of Acoustics and Music Theory in the Scientific Work of Robert Hooke," *Annals of Science* 37 (1980): 573-605.

¹³ Robert G. Frank, *Harvey and the Oxford Physiologists: Scientific Ideas and Social Interaction* (Berkeley, Los Angeles and London: University of California Press, 1980); see, also, Daniel P. Walker, "Medical Spirits in Philosophy and Theology from Ficino to Newton," *Arts du spectacle et histoire des idées* (Tours: Centre d'Etudes Supérieures de la Renaissance, 1984), pp. 287-300; Penelope M. Gouk, "Music, Melancholy and Medical Spirits in Early Modern Thought," in *Music as Medicine*, ed. Peregrine Horden (London: Ashgate, forthcoming).

Transition

3 Geometry vs Arithmetic

Paolo Gozza

A Renaissance Mathematics: the Music of Descartes

Michael Dickreiter

The Structure of Harmony in Johannes Kepler's Harmonice mundi (1619)

A RENAISSANCE MATHEMATICS: THE MUSIC OF DESCARTES*

Paolo Gozza

The more human minds blossom the sweeter are the springs of knowledge and virtue they have drunk from.¹

The adagio which in November 1616 Descartes dedicates to *Renato Brochard avunculo suo* is the measured judgement of a period of his life, emblem of an intellectual experience marked by an “industrious curiosity” (“laboriosa curiositas,”) fueled by a “curious felicity” (“curiosa foelicitas.”) To the *viro clarissimo* Descartes colourfully recalls the seductive pathways of a felicitous educative apprenticeship. His thirst for knowledge, excited but not sated by the sweet humors of the liberal arts, led him beyond the fascinating waters of poetry and the impetuous currents of eloquence. He ventured out onto the vast ocean of the sciences, exploring one by one “with carefull zeal” (“sagaci sedulitate”) all the tributaries flowing into it, eager to find one capable of sating the thirst of his intelligence. At the incontaminate fountains of virtue and knowledge the young graduate in law was finally touched by Themis who overcame his wild free nature, turning him into a fervent servant of the gracious goddess.² The follower of Themis would soon after have to face up to the obscure law of fate, and the plastic metaphor of knowledge in the *placard* would take on a dramatic tone in the *Compendium musicae*, painted for the Dedicatee as the landing after a tumultuous crossing between the hardships of destiny and temperament.³

* Published as “Una matematica media gesuita: la musica di Descartes,” in *Cristoph Clavius e l'attività scientifica dei Gesuiti nell'età di Galileo*, ed. Ugo Baldini (Rome: Bulzoni Editore, 1995), pp. 171-188, and, with variants, as “Una matematica rinascimentale: la musica di Descartes,” *Il Saggiatore Musicale* 2 (1995): 237-257.

¹ “Humana ingenia eo magis florent quo dulciores scientiarum virtutisque haustus ebiberunt.” René Descartes, “Dédicace du placard de la licence en droit,” original text and French translation edited by Jean-Robert Armogathe and Vincent Carraud, *Archives de Philosophie* 50 (1987), Bulletin Cartésien 15, p. 2.

² Ibid., pp. 2-3. A detailed analysis of the *placard* is provided by Armogathe, Carraud and Robert Feenstra, “La licence en droit de Descartes: un placard inédit de 1616,” *Nouvelles de la République des Lettres* 2 (1988): 123-145.

³ René Descartes, “Compendium musicae,” in *Oeuvres de Descartes*, ed. Charles Adam and Paul Tannery, Nouvelle Présentation, 13 vols. (Paris: J. Vrin/CNRS, 1964-1974), 10:140-141 (=AT, followed by the volume, the pages and the lines in italics). Accurate and useful is the French edition of the *Compendium musicae* with presentation and critical remarks by Frédéric de Buzon (Paris: Presses Universitaires de France, 1987); see, also,

Of the science which in November 1616 he intends to choose, Descartes demands “une connaissance claire et assurée de tout ce qui est utile à la vie.”⁴ In the curriculum of the Jesuit college Henry IV at La Flèche, issued probably in 1613, Descartes discovered a knowledge that was certain and beyond doubt:

Je me plaisais surtout aux mathématiques, à cause de la certitude et de l'évidence de leurs raisons.⁵

Mathematical disciplines, however, do not fully satisfy the requirement of knowledge useful for life. Indeed, considering that such disciplines are applied to the ‘mechanical arts’ only, and that on their solid foundations nothing great has been created, Descartes does not as yet understand “leur vrai usage.”⁶ Between these doubts and the “real use” of mathematics in physics solicited by Isaac Beeckman, music perhaps is the discipline which from his times at La Flèche Descartes has most thoroughly explored. By all accounts the young Descartes judged the discipline of music to be consistent with his own idea of science as undoubted knowledge useful for life. Among the disciplines of the Jesuit curriculum music has a special standing, associating as it does the certainty of mathematical demonstrations with the nature of man:

The purpose of music is to give pleasure and arouse in us various passions.⁷

Boethius, whose *De musica* was a manual still commented on, captures Descartes’ idea in the aphorism “musica non modo speculationi verum etiam moralitati coniuncta est,” music is a speculative science linked to morality.⁸ Aimed at *delectare et movere*, the rigour and elegance of mathematical reasoning merges in music with the love of poetry and the

Renato Cartesio, *Breviario di musica*, ed. Luisa Zanoncelli (Florence: Passigli, 1990). On the dedicatory of the *Compendium*, see the following Section of this article.

⁴ Descartes, “Discours de la Méthode,” AT, 6:4.

⁵ Ibid., p. 7; cf. Geneviève Rodis-Lewis, “Descartes et les mathématiques au collège. Sur une lecture possible de J.-P. Camus,” *Le Discours et sa méthode, Colloque pour le 350e anniversaire du “Discours de la Méthode”*, ed. Nicolas Grimaldi et Jean-Luc Marion (Paris: Presses Universitaires de France, 1987), pp. 187-211.

⁶ Ibid.; Rodis-Lewis, “Descartes et les mathématiques,” pp. 187-188.

⁷ “Finis [sc. musicae] ut delectet, variosque in nobis moveat affectus.” AT, 10:89 4-5.

⁸ Anicius Manlius Severinus Boethius, *De institutione musica libri quinque*, ed. G. Friedlein (Lipsiae: in aedibus B.G. Teubneri, 1867), I, 1; cf. Claude V. Palisca, “Boethius in the Renaissance,” *Music Theory and its Sources. Antiquity and the Middle Ages*, ed. André Barbera (Notre Dame Indiana: University of Notre Dame Press, 1990), pp. 258-280.

theatre. Music is contiguous with life,⁹ corporeal form which acts through harmony.¹⁰ A metaphor for life, music claims the whole man as its own,¹¹ it is recognition and communication:

It is for this reason alone that we most like the human voice, since of all things it most conforms to our spirits. We therefore find the voice of the friend much more pleasant than the voice of our enemy, on account of the sympathy and antipathy of the affections.¹²

The unity of life is expressed in music, and music is a stage in the Cartesian search for the unity of the sciences. An admirable synthesis of Descartes' scholastic view on Renaissance musical science elaborated before the 'mathématique universelle' and method, the *Compendium musicae* heralds both 'mathématique universelle' and method, while the last piece of work published by Descartes addresses the issue that the 1618 musical treatise has turned down:

a more accurate study of this matter (i.e., of the various affections that Music can arouse in our souls with different rhythms) depends on a perfect knowledge of the motions of the soul, on which I say no more.¹³

⁹ Boethius, *De musica*, I, 1: "Musicam naturaliter nobis esse coniunctam et mores vel honestate vel evertere."

¹⁰ "Sensible things are suited to represent high-minded things: wind signifies spirit, motion with time means life... Each sensible form acts through harmony" ("Sensibilia apta concipiendis Olympicis: ventus spiritum significat, motus cum tempore vitam... Omnis forma corporea agit per harmoniam":) Descartes, "Cogitationes Privatae," AT, 10:218 6-7.

¹¹ It is the whole man that Descartes wants in Beeckman, dedicatee of the *Compendium*: "Your letters were welcome and awaited, and I was immediately uplifted when I recognized your musical sketches... You must believe that I do not care for science alone, but for you; and not just for the mind, even if it is the noblest part, but for the whole man" ("Et acceptae & expectatae mihi fuerunt tuae litterae, gavisusque sum primo intuitu, cum Musicae notas inspexi... Neque enim scientiam solam, sed te ipsum mihi curae esse debuisti credere; nec ingenium solum, etiamsi pars sit maxima, sed hominem totum:") AT, 10:151 1-8.

¹² "Id tantum videtur vocem humanam nobis gratissimam [reddere], quia omnium maxime conformis est nostris spiritibus. Ita forte etiam amicissimi gratior est, quam inimici, ex sympathia & dispathia affectuum:" AT, 10:90 1-7. "For the same reason they say that the skin of the lamb stretched on the drum does not sound, after being beaten, when the skin of the wolf sounds on another drum" ("eadem ratione qua aiunt ovis pellem tensam in tympano obmutescere, si feriat, lupina in alio tympano resonante;") cf. Frédéric De Buzon, "Sympathie et antipathie dans le *Compendium musicae*," *Archives de Philosophie* 46 (1983): 647-653.

¹³ "huius rei [i.e., variorum affectuum, quos varia mensura Musica potest excitare] magis exacta disquisitio pendet ab exquisita cognitione motuum animi, de quibus nihil plura:" AT, 10:95 21-23. Descartes' last work is *Les passions de l'âme*, published in 1649, one year before his death in February 1650.

'Descartes secret'

Henri Gouhier, the refined commentator of the "premières pensées de Descartes," discovers in a text of *Compendium musicae* the document "d'une vie profonde" of Descartes, "qui est une vie secrète."¹⁴ Gouhier compares the dedicatory to Beeckman in the closing page of the *Compendium* with Descartes' letters to his friend on "la science entièrement nouvelle."¹⁵ The expressions of these texts suggest to Gouhier that Descartes' famous *larvatus prodeo* (I advance masked) grows out of an older antinomy of his: "indolent and free" ("desidioso et libero"),¹⁶ [a man] "who does and conceives things in different ways" ("penitusque diversa cogitante et agente"), versus rediscovery of one's vocation and "science entièrement nouvelle:"

le jeune français est arrivé en Hollande dans cette disposition qu'expriment les mots desidiosus et desidia de ses lettres; or quelques mois plus tard, les sciences ne sont plus pour lui une espèce d'amusement mais le but de sa vie.¹⁷

C'est ce contraste entre sa vie extérieure et sa vie intérieure qu'exprimera bientôt le fameux texte: *larvatus prodeo*.¹⁸

For the first time music seems to provide the historian of Descartes with the basic tonality of the movement of ideas which in the crucial years 1618-1621 led him to the heights of Olympus. In actual fact, the *Compendium* speaks to Gouhier on its final page only, the rest being extraneous to the austere anti-Renaissance philosopher who with no remorse leaves Descartes' music to the musicologists.¹⁹ Will this 'secret' of Descartes, that

¹⁴Henri Gouhier, *Les premières pensées de Descartes. Contribution à l'histoire de l'anti-Renaissance* (Paris: J. Vrin, 1958), p. 29.

¹⁵ The letters are dated 26 March and 23 April 1619; cf. AT, 10:154-160, 162-164.

¹⁶ "désoudre et diletante," Gouhier translates (*ibid.*, p. 30); "et non libero," proposes Adam (AT, 10:141a), who refers the Reader to Descartes' letter to Beeckman of 26 March 1619: "if I succeed in overcoming my innate indolence, and the fates grant me a free life" ("si desidiam innatam possim vincere, & fata liberam vitam indulgeant,") AT, 10:156, and underlines "la traduction embarrassée" first by Poisson then by Baillet reported on pp. 86-87.

¹⁷ Gouhier, *Les premières pensées*, p. 29.

¹⁸ *Ibid.*, p. 30.

¹⁹ It is not possible here to discuss the literature which has generally operated in such a way as to make the *Compendium musicae* unrecognizable to its Author and its time (e.g., Johannes Lohmann, "Descartes' *Compendium musicae* und die Entstehung des neuzeitlichen Bewußtseins," *Archiv für Musikwissenschaft* 36 (1979): 81-104). There are important exceptions, above all the admirable *Descartes et la musique* (Paris: Fischbacher, 1907; reprint ed., Genève: Minkoff, 1977) by André Pirro. Pirro points out the insensibility of the young mathematician to the allure of sensible music (indeed, Descartes' indifference "à tout le sensible:" on p. 76) and considers the *Compendium* "un chapitre de la

felicitous contrast Gouhier finds at the close of *Compendium musicae* as its seal, not instead be the philosophy of his youthful treatise, premise to “le période de fièvre créatrice” which music projects into the future?

In the *Compendium* Descartes takes his leave of Beeckman by recalling that the work “has been tumultuously composed here amidst the ignorance of the army by an indolent and [not] free man, who thinks and does things altogether different, only for sake of your love.”²⁰ When he parts with his “creation,”²¹ entrusting it to his friend, Descartes highlights the precarious conditions of its gestation, the coming ashore after the tumultuous voyage evoked in the incipit *Iamque terram video, festino ad littus* (and I at last see land, I hurry towards the shore). The rocks and whirlpools that lay in wait for Descartes are in the text the rough uncultured military life and the apathy of his own temperament: the ‘unmusical man’ of the *encomium musicae*, on the one hand, insensitive to music,²² the melancholic mood on the

‘mathématique universelle,’ ” (p.124) indirectly offering an opportunity that Descartes’ historian has not taken: the unconvincing pages devoted to the *Compendium* in the Cartesian biographies, where there is everything and the opposite of everything, do not represent a proper synthesis of the work. Only recently have historians of science reopened the *Compendium*. This is the case of the brilliant *Quantifying Music. The Science of Music at the first Stage of the Scientific Revolution* (Dordrecht / Boston / Lancaster: D. Reidel, 1984), p. 161ff., by Floris Cohen, who more than anyone else has rekindled the interest of historians in the musical writings of modern scientists. William R. Shea devotes to Descartes’ musical ideas an entire chapter of his *The Magic of Numbers and Motion. The Scientific Career of René Descartes* (Canton, Ma: Science History Publications, 1991), pp. 69-92, in which the Author collects various arguments completely ignoring the *Compendium*’s chapter on musical time, the most original of the whole work, where Descartes shows himself more sensitive to the philosophical allure of music and its capacity to provoke epistemological reflections of importance for his “scientific career.” It is no coincidence that, after the work of Pirro, the most incisive contribution towards understanding the *Compendium* is the essay of a musicologist aiming at reconstructing the history of the idea of ‘rhythm’, Wilhelm Seidel, whose “Descartes’ Bemerkungen zur musikalischen Zeit,” *Archiv für Musikwissenschaft* 27 (1970): 287-303, argues against earlier musicologists who have aligned Descartes’ analysis of musical time to the prehistory of classical theory of musical period, e.g., Heinrich Bessler’s *Das musikalische Hören der Neuzeit* (Berlin: Akademie-Verlag, 1959). See, also, Frédéric De Buzon, “Fonctions de la mémoire dans les traités théorique au XVI^e siècle,” *Revue de Musicologie* 76 (1990): 163-172.

²⁰ “hic inter ignorantiam militarem ab homine desidioso & libero, penitusque diversa cogitante & agente, tumultuose tui solius gratia esse compositum:” AT, 10:141 9-12.

²¹ Ibid., 140 26-27: “hunc ingenii mei partum, ita informem, & quasi ursae foetum” (“this gestation of my mind, so shapeless, and almost the foetus of a bear.”)

²² “The man that hath no music in himself” from the speech of Lorenzo in the *Merchant of Venice* by William Shakespeare, skillfully acted in the light of the tradition of *encomium musicae* by James Hutton, “Some English Poems in Praise of Music,” *English Miscellany*, 2 (1951): 1-63, now in his *Essays on Renaissance Poetry*, ed. Rita Guerlac (Ithaca and London: Cornell University Press, 1980), pp. 17-73.

other, which seeks in music relief and remedy.²³ The contrast, captured in the striking image “ab homine penitusque diversa cogitante & agente,” explains the ambivalence of Descartes’ dedication to Beeckman: an attestation of modesty, with an entreaty to Beeckman that his shapeless creation should remain hidden forever among his papers, and an awareness and pride in his intelligence: “nonnulla certe ingenji mei lineamenta ad vivum expressa,” “some features of my mind vividly expressed.”²⁴

Contrast, tension of opposites: this is a condition familiar to Descartes, who in his *Cogitationes privatae* remarks: “The transition from one passion to another passion is via the nearby passions; often however transition via contrary passions is more effective.”²⁵ Written in a few, intense weeks (*tumultuose*) for his friend, Descartes’ first work until the *Regulae ad directionem ingenii* (1627/28) is above all the extraordinary result of a vital contradiction: inertia, opacity of reality, melancholy on the one hand, *furor geometricus* dictated by music on the other. Inspired by his friendship for Beeckman, the limpid pages of the *Compendium musicae* are the result of a feverish research into the geometric order inherent in the movement of life, into harmony as a law of experience and knowledge.

The stage upon which the elegant edifice of musical theory is raised displays the same essential tension. In music Descartes seeks agreement between sense and reason, between the judgement of the ear and the judgement of the mind. Between life and science there is not only opposition but also continuity and agreement: musical theory expresses by means of reason the dynamism of voices, analogous to the movement of life, which finds its own perfection in the experience of pleasure.²⁶ Descartes, whom Gouhier encounters at the end of *Compendium musicae*, experienced the knowledge that is useful for life: pleasure is possible where there

²³ The melancholy-music binomial is a Humanistic-Renaissance constant: cf., e.g., Daniel P. Walker, “Ficino’s Music-Spirit Theory,” in his *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute/University of London, 1958), pp. 1-11.

²⁴ AT, 10:141 7-8.

²⁵ “Transitus à passione in passionem, per vicinas; saepe tamen à contrarijs validior transitus.” Descartes, “Cogitationes privatae,” AT, 10:217. The third of the *regulae componendi* (rules of composition) of the *Compendium* says: “Ut, quantum fieri potest, motibus contrarijs partes incedant. Quod fit ad maiorem varietatem: tunc enim perpetuo & motus cuiusque vocis ab adversa, & consonantiae à vicinis consonantjis sunt diversae” (“The parts should move as far as possible through contrary motions. All of which produces greater variety: thus the motions of each voice are different from the opposite one, and the consonances are different from those next to them:”) AT, 10:132 31 - 133 1-4. On the ‘practical’ section of the *Compendium*, which would take us a long way from the subject of this paper, cf. Pirro, *Descartes*, pp. 47-89.

²⁶ Cf. Aristotle, *Ethica Nicomachea*, X, esp. 4, 1174b-1175a: 1175a, 20: “... pleasure and life seem linked and it is not possible to separate them; in fact, without activity there is no pleasure and pleasure perfects every activity.”

is agreement between the sense and reason; harmony and geometric order are the secret reality of things, the intimate law of existence and thought.

The object of music

Sound which is generated by voices or instruments is not the proximate object of music:

Let the natural philosophers study the quality of sound, from which body [sound] is produced and under which conditions it may be most pleasing.²⁷

The nature of sound, its physical properties as well as the material conditions for its generation, production and transmission, are the subject of *physica*, the science that studies the principles and causes of natural substances. Music has a different ranking among the theoretical sciences, it belongs to the mathematical disciplines whose subject is quantity.²⁸ The mathematician simplifies the complex nature of sound: it separates from the substance of sound its quantitative properties, *numerus et mensura*, and leaves to the natural philosopher the search for physical causes.²⁹ The divorce between mathematics and natural philosophy is made clearer in the text by the decision of the young mathematician to leave qualitative explanations to the Aristotelian professors of natural philosophy. Descartes is here the pupil of Cristoph Clavius (1538-1612), conferring on music the primacy of the mathematical disciplines over physics that the Jesuit mathematician had posited at the core of his reformed curriculum.³⁰

The subject of musical theory is therefore sound insofar as it is ontologically defined by the category of quantity, continuous and discrete. The object of hearing delights the sense to the extent that beneath its qualita-

²⁷ "de ipsius soni qualitate, ex quo corpore & quo pacto gratior exeat, agant Physici:" AT, X, 89 12-13.

²⁸ Cristoph Clavius, "Prolegomena" to his *Euclidis Elementorum libri XV*, 2 vols. (Rome: apud Vincentium Accoltum, 1574), 1:5^r; cf. William A. Wallace, *Galileo and Its Sources. The Heritage of the Collegio Romano in Galileo's Science* (Princeton: Princeton University Press, 1984), pp. 136-41, and Peter Dear, "Jesuit Mathematical Science and the Reconstitution of Experience in the Early Seventeenth Century," *Studies in History and Philosophy of Science* 18 (1987): 133-175. See, also, Eberhard Knobloch, "L'Oeuvre de Clavius et ses sources scientifiques," *Les jésuites à la Renaissance. Système éducatif et production du savoir*, ed. Luce Giard (Paris: Presses Universitaires de France, 1995), pp. 263-283.

²⁹ Cf. AT, 10:95 1-3: "certum enim est sonum omnia corpora circumquaque concutere, ut advertitur in campanis & tonitru, cuius rationem Physicis relinquo." ("it is well known that sound makes surrounding bodies vibrate, as can be heard in bells and thunder, the reason of which I leave to the Natural Philosophers.")

³⁰ Dear, "Jesuit Mathematical Science," pp. 164-67; Knobloch, "L'Oeuvre de Clavius," p. 263 ff.

tive, sensible surface, it reveals a deep geometrical structure. It is through the quantitative properties of sound that music achieves its goal:

In view of the aim [i.e., to give pleasure and arouse passions] the means of music are basically two properties of sound: the ratios of duration or tempo, and of pitch in relation to acuteness and loudness.³¹

The mathematical statute of its object explains the special position of music among the disciplines of quantity in the traditional quadrivium. In his *Prolegomena to Euclidis elementorum libri XV* (*Introduction to the XV Books of Euclid's Elements*), Clavius adopts from Proclus' *Commentaries* to Euclid a twofold classification of mathematics. In the Pythagorean quadripartition, codified by Nicomachus of Gerasa and taken up by Iamblicus, Proclus and Boethius, the subject of music is discontinuous or discrete quantity (i.e. number) in relation to another discontinuous subject (i.e. sound); before it comes arithmetic which actually studies discrete quantity *per se* (i.e. number with no relation to another subject).³² A second *divisio mathematicarum* that Proclus attributes to Geminus is based not on quantity but the distinction of sensible and mental objects of knowledge. In this classification, *canonica sive musica* is, with astrology, optics and mechanics, a middle mathematics whose subject is sensible, unlike pure mathematics (arithmetic and geometry) whose subjects are mental.³³

Descartes accepts these canonic distinctions in his description of the object of music. Music is a mathematical discipline whose object is quantity. Furthermore, since sound is perceived by the senses, music is a middle or mixed mathematics. On these grounds Descartes' *Compendium musicae* holds an intermediate position within the musical tradition, between the Pythagorean assumption of the primacy of numbers and the Aristoxenian

³¹ "Media ad finem [i.e. delectare et movere], vel soni affectiones duae sunt praecipue: nempe huius differentiae, in ratione durationis vel temporis, & in ratione intensionis circa acutum aut grave." AT, 10:89 9-12.

³² Clavius, "Prolegomena," 7^v-8^v; Francesco Barozzi, "Prologus" to his *Procli Diadochi... in primum Euclidis Elementorum librum Commentariorum ad universam mathematicam disciplinam principium tradentium libri IIII* (Padua: exc. Gratosius Perchacinus, 1560), I, xii. See Eckhard Kessler, "Clavius entre Proclus et Descartes," in *Les jésuites à la Renaissance*, pp. 285-308.

³³ Clavius, "Prolegomena," 5^r-6^v; Barozzi, "Prologus," I, xiii. See, also, Giuseppe Biancani (J. Blancanus), "Apparatus ad Mathematicas addiscendas, et promovendas," in the Appendix to his *Sphaera Mundi seu Cosmographia* (Bononiae: Typis Sebastiani Bonomj, 1620), pp. 387-414, who in his *divisio mathematicarum* follows Geminus: "forte Geminum imitabor" (p. 387). On Geminus cf. Paul Tannery, *La Géométrie Grecque* (Paris: Gauthier-Villars, 1887; reprint ed., New York: Arno, 1976), pp. 18-52, and Germaine Aujac, *Géminos Introduction aux Phénomènes* (Paris: Les Belles Lettres, 1975), pp. ix-xxxvii.

assumption of the primacy of hearing.³⁴ Following Ptolemy's attempt to harmonize the judgement of the mind and the judgement of hearing,³⁵ the Cartesian treatise enlivens the Ptolemaic school of thought drawing on the Aristotelian criterium of agreement between reason and sense.

The Aristotelian criterium of truth postulates the homogeneity between the premises of a science and its subject in such a way as to allow the possibility of a logico-deductive nexus between the principles and the conclusions.³⁶ The problem of *praecognita*—presupposed and indemonstrable knowledge that allows someone unacquainted with a subject to tackle it³⁷—is particularly pressing for the middle and lower sciences which must draw from the prior and higher sciences the principles on which to base their conclusions. The problem is clearly underlined in a book on music theory in the Jesuit curriculum, Jacques Le Febvre d'Étaples' *Musica demonstrata*, that suggests a way round the difficulty:

Subordinate science, as music is to arithmetics, makes use of the principles and demonstrations of the prior, subordinating science: however we have tried as far as possible to make this occur rarely in this discipline; thus, where convenient, we shall use a method of demonstration different from that applied to arithmetics.³⁸

In order to ensure continuity from the principles to demonstrations the subordinated middle sciences premise, alongside the *dignitates* or *axiomata* common to all sciences, special *praecognita* homogeneous with their subject. Ahead of the common notions Faber proposes his own list of prin-

³⁴ On the two ancient schools of music, see, e.g., the very erudite Giovanni Battista Riccioli, *Almagestum novum astronomiam veteremque novamque complectens*, 2 vols. (Bononiae: ex typ. haeredis Victorij Benatij, 1651), 1:507 ff.

³⁵ Ptolemy, *Harmonics*, I, 1, in *Greek Musical Writings*, ed. Andrew Barker, 2 vols. (Cambridge: Cambridge University Press, 1984-1989), 2:276ff.

³⁶ Dear, "Jesuit Mathematical Science," p. 138.

³⁷ Aristotle, *Analytica Posteriora*, I, 1, 71a1-b8; cf. Wallace, *Galileo*, p. 99ff.

³⁸ "Scientia subalternata, qualis ad arithmetica musica est, principiis & demonstratis scientiae prioris subalternantisque utitur: at studuimus ut quam fieri potest rarissime in hac disciplina fiat: verum plerumque ubi oportuna videbitur, alio quam in arithmetice factum est utemur demonstrandi modo." Jacobus Faber Stapulensis, *Musica libris demonstrata quatuor* (Paris: apud Gulielmum Cavellat, 1551²), 4^r; cf. Biancani, "Apparatus ad Mathematicas Addiscendas," p. 401: the teaching of musical theory begins "from Jacques Le Febvre d'Étaples' Music, which he explains clearly and briefly in four Books, called *Elementa Musicalia*... ; then Boethius' Music will be read." ("à Musica Iacobi Fabri Stapulensis, quam ipse quatuor libris perspicue, et breviter exponit, appellatque Elementa musicalia... ; postea legatur Musica Boethii.") Another possible source of Descartes' *Compendium* is Francesco Maurolico's "Musicae traditiones captim collectae, vel musica elementa," published in his *Opuscula mathematica* (Venice: apud Franciscum Franciscum Senensem, 1575), pp. 145-160; on Maurolico see Rosario Moscheo, *Francesco Maurolico tra Rinascimento e scienza galileiana. Materiali e ricerche* (Messina: Società messinese di storia patria, 1988).

ciples, the musical definitions, and ends them with a further list of *praecognita*, the *petitiones*, which the Aristotelian commentators explain as *praenotiones* on which the teacher demands temporary agreement.³⁹ In his *Dimostrazioni harmoniche* Zarlino works with the same epistemological parameters. The introductory pages of “Ragionamento Primo” summarize the epistemological cornerstones of the debate on the demonstrative method within the framework of Aristotle’s *Analytica posteriora* and the *Commentarii* of Proclus in *primum Euclidis Elementorum*, establishing the premises in a like manner to Faber Stapulensis.⁴⁰ Faber and Zarlino both try to axiomatize music—transform the scholastic musical treatise into a modern *more euclideo* treatise.

The same issues underlie the *Compendium musicae*, which is an elegant Renaissance model of a demonstrative musical treatise. Descartes also has his list of *praecognita*, the *praenotanda*, which correspond to the need for middle mathematics to show an order of presentation of principles that is different to that of pure mathematics, starting with what is most evident to the senses and reason together rather than just reason alone.⁴¹ In the premises of the *Compendium*, what is evident to sense and reason is the simplest geometrical magnitude, the line, and its division into equal parts related to each other in arithmetic proportion.⁴² Between sense and reason there is thus proportion, hence pleasure, while the opposite causes pain.⁴³

³⁹ Faber Stapulensis, *Musica*, 3^v-4^r; cf. Wallace, *Galileo*, p. 105.

⁴⁰ Gioseffo Zarlino, *Dimostrazioni harmoniche* (Venice: per Francesco dei Franceschi Senese, 1571), pp. 7-18. See Michael Fend, “Zarlinos Versuch einer Axiomatisierung der Musiktheorie in den *Dimostrazioni harmoniche* (1571),” *Musiktheorie* 4 (1989): 100-112.

⁴¹ A different statute of the object, for example the metaphysical object, lays out a different order of presentation, cf. Descartes, “Rationes Dei existentiam & Animae a corpore distinctionem probantes more geometrico dispositae” (“Arguments that demonstrate the existence of God and the distinction between Soul and body, set down in geometrical order:”) AT, 7:160 ff.: here the premises are, in order, “Definitiones, Postulata, Axiomata sive Communes notiones.” (“Definitions, Postulates, Axioms or Common notions.”)

⁴² AT, 10:91 28 - 92 1-11: “proportio linearum:

2 |—————|—————|

3 |—————|—————|—————|

4 |—————|—————|—————|—————|

facilius oculis distinguitur, quàm harum,

2 |—————|

$\sqrt{8}$ |—————|—————|

4 |—————|—————|—————|
a b c

The act of seeing which in the *praenotanda* captures the proportion between the parts of the whole is an intellectual act, an intuition. But when we move from the static objects of vision to the moving objects of hearing, the relationship between *ratio* and *sensus* is not immediate but mediated. An analysis of duration reveals the nature and mode of this mediation.

The musical continuum

A few weeks after the drafting of his *Compendium musicae*, in a letter to Beeckman of 26 March 1619, Descartes makes the usual allusion to his “innata desidia” and unfree destiny,⁴⁴ tying it in with the heroic plan of establishing:

a completely new science..., which can be used to solve all the questions that can be raised for all kinds of quantity, continuous as well as discrete... An unending task... Incredibly ambitious.⁴⁵

The development which led Descartes to *musica instrumentalis* extends to *musica intellegibilis*: the science of continuous and discrete quantity as regards to musical sound—the object of reason linked to sense—paves the way for the study of continuous and discrete quantity abstracted from matter—the subject of *ratio* alone, a preamble to the *mathesis universalis*.⁴⁶ Sound is both a continuous and a discrete quantity: the temporal continuum is the substratum to discrete numerical values (the pitches of notes) which exist in it and follow one another. The two quantifiable attributes of

quia, in prima, oportet tantum advertere unitatem pro differentia cuiusque lineae; in secunda vero, partes *ab* & *bc*, quae sunt incommensurabiles, ideoque, ut arbitror, nullo pacto simul possunt a sensu perfecte cognosci, sed tantum in ordine ad arithmeticae proportionem: ita scilicet, ut advertat in parte *ab*, verbi gratia, duas partes, quarum 3 in *bc* existant. Ubi patet sensus perpetuo decipi.” (“The ratios of the lines... is more easily perceived by our eyes than the ratios between these lines... ; for, in the former, only unity must be considered as difference of each line; in the latter, in contrast, we must consider *ab* and *bc*, which are incommensurable, which means, I believe, they cannot be simultaneously conceived by sense in a proper manner, but only in relation to arithmetical proportionality; so that sense perceives *ab* as divided into two parts, three of which are found in *bc*. Whence it is plain that the sense is always wrong.”) See Seidel, “Descartes’ Bemerkungen,” pp. 289-294.

⁴³ Ibid., 3-9 (first and second premise); the source is Aristotle’s *De anima*, III, ii, 426a 28 - 426b 8.

⁴⁴ See above note 16.

⁴⁵ “scientiam penitus novam..., qua generaliter solvi possint quaestiones omnes, quae in quolibet genere quantitatis, tam continuae quam discretæ, possunt proponi... Infinitum quidem opus... Incredibile quam ambitiosum:” AT, 10:156 7 - 157 3, 22-23.

⁴⁶ Cf. Descartes, “Regulae ad directionem ingenii,” Regula IV, AT, 10:377ff.

musical sound, duration and pitch, are what distinguish the *Compendium musicae* among Renaissance musical treatises. Descartes does not limit the theory of music to the canonical deduction and classification of the sounding numbers. The deduction of consonances is preceded in the *Compendium* by an analysis of the other attribute of sound, musical time. The novelty is reflected in the *divisio rerum* of the musical treatise as genre codified by a centuries-old tradition:

(*musica theorica*): Object (chapter 1), Praenotanda (chapter 2), Musical Time (chapter 3), Intervals (chapters 4 to 11);

(*musica activa*): Rules of composition and modes (chapters 12 to 13), Dedication to Beeckman.

The new *divisio rerum* points to a logical priority: time is the primary dimension of musical space, pitch and verticality come second:

I will not omit to say however that the power of rhythm in Music is so great that this alone can give pleasure: this is clear with the drum, a warring instrument, where nothing else is considered except measure.⁴⁷

Pitch-values of notes are an abstraction from the perceived musical continuum, discrete quantities that atomize the movement of voices in time, a stasis of motion. Music is on the other hand a living unity of the values of notes duration and pitch merging in the auditory experience of listening.

Musical time in the *Compendium* introduces musical perception. As sensible order of motion, rhythm makes music perceptible, it is the *conditio sine qua non* of the perception of music as a dynamic whole. The problem comes to the fore when from the single musical measure, *membrum cantilenaе*, perception follows the measures' succession in time. Here *sensus non sufficit*; it should as it were expand and extend itself following the extension of the measures through time. This temporal extension of the sense does exist and is called *imaginatio*. Like sense, Descartes' imagination is corporeal; furthermore, unlike Aristotle's fantasy which is defined passively vis-à-vis sensation, it has the power of composition, is synthetic not merely reproductive, catalectic.⁴⁸

⁴⁷ "Non omittam tamen tantam esse vim temporis in Musica, ut hoc solum quandam delectationem per se possit afferre: ut patet in tympano, instrumento bellico, in quo nihil aliud spectatur quam mensura." AT, 10:95 24-27; cf. De Buzon, "Fonctions de la mémoire," p. 168.

⁴⁸ On these characteristics of the Cartesian *imaginatio*, cf. Descartes, *Règles utiles et claires pour la direction de l'esprit en la recherche de la vérité*. Traduction selon le lexique cartésien, et annotation conceptuelle par Jean-Luc Marion, avec des notes mathématiques de Pierre Costabel (La Haye: M. Nijhoff, 1977), pp. 122-125. See, also, Dennis L. Sepper, *Descartes's Imagination. Proportion, Images, and the Activity of Thinking* (Berkeley/Los Angeles/London: University of California Press, 1966).

This happens, if the whole melody consists of either 8, or 16, or 32, or 64 parts, and so on, in such a way that all these divisions derive from the double proportion. For then, while listening to the first two measures, we conceive them as one; while listening to the third, we again link it with the previous ones, so that they are in triple proportion; then, when listening to the fourth, we link it to the third, so as to conceive them as one; then we again join the first two with the latter two, so that we simultaneously conceive these four measures as one. And thus our imagination proceeds all the way to the end, where at last it conceives the entire melody as a whole fused out of many equal members.⁴⁹

Different issues are woven together in the imagination of the *Compendium*. How can a temporal succession of parts one external to each other be a living musical whole? how can a mechanical sequence of points be a musical phrase, a dynamic organism capable to give pleasure and move the soul? Imagination in Descartes' *Compendium* is precisely the temporal faculty of the soul that transforms a succession of disparate parts into an articulated and living whole. Sense perceives and distinguishes within a single measure the three ratios of notes duration allowed: *aequalitas* 1:1, *proportio dupla* 2:1 e *proportio tripla* 3:1.⁵⁰ Imagination extends these ratios to the whole melody. It converts the sonorous event into an inner, perceptual object fused out of equal and symmetrical parts.⁵¹ Listening is thus imagining the perceived object as a geometrical structure perhaps similar to that of the lines in arithmetic proportion which in the premises to the *Compendium* are the model of clear and distinct perception.⁵² The actual element of duration in the inner geometry of imagination is the accented note of the musical measure, "which helps our imagination, with which we can more easily perceive all the measures of the melody, and take pleasure

⁴⁹ "quod fit, si tota cantilena vel 8, vel 16, vel 32, vel 64 &c., membris constet, ut scilicet omnes divisiones a proportione dupla procedant. Tunc enim, dum duo prima membra audimus, illa instar unius concipimus; dum tertium membrum, adhuc illud cum primis coniungimus, ita ut sit proportio tripla; postea, dum audimus quartum, illud cum tertio iungimus, ita ut instar unius concipiamus; deinde duo prima cum duobus ultimis iterum coniungimus, ita ut instar unius illa quatuor concipiamus simul. Et sic ad finem usque nostra imaginatio procedit, ubi tandem omnem cantilenam ut unum quid ex multis aequalibus membris conflatum concipit." AT, 10:94 8-20. On this text and on Chapter 3 "De numero vel tempore in sonis observando" as a whole, see the incomparable reading by Seidel, "Descartes' Bemerkungen," p. 297ff. See, also, de Buzon, "Fonctions de la memoire," p. 169 ff., and Sepper, *Descartes's Imagination*, pp. 44-45.

⁵⁰ AT, 10:92 23-25 - 93 1-3; other ratios are not allowed since it is hard to perceive them by the sense.

⁵¹ Ibid., 94 19-22 - 95 1-20; cfr. Seidel, "Descartes' Bemerkungen," pp. 297-299.

⁵² See note 42 above.

from the proportion that should be within them.”⁵³ The accented note at the beginning of each measure is “a greater loudness of the voice in vocal music, and of touch in musical instruments,”⁵⁴ by means of which sound excites more the ear and the animal spirits “that solicit us to motion.”⁵⁵ Singers and instrumentalists know well that at the beginning of each bar “sound is uttered more clearly,” “especially in those melodies to whose rhythms we are accustomed to dance and tripudiate to; there the rule is observed, to distinguish each measure of the music with each motion of our body.”⁵⁶ In the music for dance ‘the number of motion’ is made sensible in the body of the dancer. The body is imagination: “the imagination itself along with the ideas it contains [is] nothing more than a really material body possessing extension and figure.”⁵⁷ Dancing is a metaphor of imagination, *unum simul* of equal parts blended into each other—*unum quid ex multis aequalibus membris conflatum*: organic unity animated by the warm breath⁵⁸ of the *spiritus (imaginatio)*, the bond between the soul and the body through which pleasure takes place as the accord between *ratio* and *sensus*.

The discrete

In no other subject are mathematical ratios more clearly discerned than in geometry:

Though one thing can be said to be more or less white than another, or a sound sharper or flatter, and so on, it is yet impossible to determine exactly whether the greater exceeds the less in the proportion two to one, or three to one, &c., unless

⁵³ “quod fit ad juvandam imaginationem nostram; qua possimus facilius omnia cantilenae membra percipere, & proportione quae in illis esse debet delectari.” AT, 10:94 1-4.

⁵⁴ Ibid., 24-25: “spiritus intensio[ne] in vocali musica, vel tactus in instrumentis.”

⁵⁵ Ibid., 95 7-9: “a quibus ad motum excitamur.” “Unde sequitur etiam feras posse saltare ad numerum, si doceantur et assuescant, quia ad id naturali tantum impetu opus est” (“Whence it comes that even wild beasts can dance in time, when trained and accustomed, since only natural motion is necessary to it.”)

⁵⁶ Ibid., 94 27-30: “distinctius sonus emittatur,” “praecipue in cantilenis ad quarum numeros solemus saltare & tripudiare: haec enim regula ibi servatur, ut singulis corporis motibus singulas Musicae battutas distinguamus.”

⁵⁷ “phantasiam ipsam cum ideis in illa existentibus nihil aliud esse... quam verum corpus reale extensum & figuratum.” Descartes, “Regulae ad directionem ingenii,” Regula XIV, AT, 10:441 11-13; cf. Descartes, *The Philosophical Works*, trans. Elizabeth S. Haldane and G.R.T. Ross, 2 vols. (Cambridge: Cambridge University Press, 1979¹³), 1:56.

⁵⁸ “conflatum” from “conflare,” to fuse each part in the unity of the compound by the flame fueled by the air.

we treat the quantity as being in a certain way analogous to the extension of a body possessing figure.⁵⁹

Descartes' sentence underscores the theoretical premise that his deduction of musical intervals in the *Compendium* is based on. The analogy between sound and geometrical space allows for mathematically calculating the distance or interval between the pitches of two different sounds. A given sound can be divided into equal parts in such a way that the second is generated by the first, the third by the second, and so on. The series thus obtained refers to the relations of pitch of musical sounds according to the analogy between sound and extension, between the subsequent divisions of the line and the musical intervals thus defined. The homogeneity between geometric and musical deduction that middle science calls for is expressed in the *Compendium* with the lexicon of the musical textbook adopted in Jesuit teaching:

Sound is to sound what string is to string.⁶⁰

The Cartesian lemma is in effect sculpted at the temple of mathematically inspired musical theory, the so-called Pythagorean. In the axiomatic *dispositio* of Faber Stapulensis' *Elementa musicalia* the principle does in fact appear among the *praecognita*.⁶¹ Zarlino, taking it from Faber, repeats Descartes' axiom in his demonstrative dialogue.⁶² The logical acumen of Descartes also comes to the fore in this circumstance. In the *Compendium* the principle of the deduction of sonorous numbers does not appear among the *praenotanda* but only in chapter 5 "De consonantiis." The *praenotanda* define the general conditions by virtue of which music achieves its end, the principle that sound is to sound what the string is to the string does not have this universality. Its field of application is the deduction of consonance, in the *Compendium* it is therefore close to the consequences that de-

⁵⁹ "quamvis enim una res dici possit magis vel minus alba quam altera, item unus sonus magis vel minus acutus, & sic de caeteris, non tamen exacte definire possumus, utrum talis excessus consistat in proportionem dupla vel tripla, &c., nisi per analogiam quamdam ad extensionem corporis figurati." Descartes, "Regulae ad directionem ingenii," Regula XIV, AT, 10:441 15-20; cf. Descartes, *Works* 1:56.

⁶⁰ "sonus se habet ad sonus, ut nervus ad nervum:" AT, 10:97 6-7.

⁶¹ Faber Stapulensis, *Musica demonstrata*, p. 4: "Petitiones. I Data aequali chorda, quae spacij ad spacium proportio est, eam esse & soni ad sonum" ("Questions. I Given an equal string, the ratio of one space to another is the same as the ratio of one sound to another.")

⁶² Zarlino, *Dimostrazioni*, p. 147: "Dimanda prima: Tirrata una corda eguale, quella proportionem, che si trova da spacio a spacio, quella istessa sia da suono a suono" ("First Question: Given an equal stretched string, let the ratio that is found from space to space, be the same from sound to sound.") The same principle is taken up by Jean-Philippe Rameau, who in his *Traité de l'harmonie* (1722) uses it as criterion for deducing the consonances, see note 71 below.

rive from it. Furthermore duration, which for Descartes precedes pitch, presupposes the synthesis of imagination through extension, while deduction implies an analytic procedure.

From the analogy between sound and geometry Descartes draws the syllogism:

Just as each string contains all its minor strings and not its major ones, so every sound contains all its higher sounds and not its lower ones.⁶³

The *nervus* (string) Descartes uses for the deduction of consonances does not have a different statute to that of the mathematical-musical tradition. It is a mental string for a mental eye, not a physical string for a natural ear. The dimensions of the Cartesian string are not its tension, cross-section, the mass of material it is made up of; its sole dimension is length, a geometric magnitude. Unlike the string described by Fracastoro⁶⁴ which has motion and rest, *itus et reditus* (the go-and-from), moves the medium, strikes the eardrum with periodical hits (*ictus*), and which in the 17th century is protagonist of the experimental musical science, the one-dimensional string of Descartes is static, is a geometric metaphor: *musica ancilla geometriae*.

The general principle that a string contains the minors just as a sound contains its higher sounds has a first 'demonstrative' application: in the *Compendium* the first six divisions of the string engender ratios corresponding to those of the first consonances.⁶⁵ This, however, is not a deduction of the consonances, a deduction *tout court*: it does not give rise to a logical order of relationships, to a classification of the ratios deduced. The principle should moreover be adjusted to the statute of middle science, i.e. a universally accepted empirical event should intervene, such as to sensibly show the theoretical evidence.⁶⁶ This evidence common to *sensus* and *ratio* is the resonance of the octave whenever there is musical sound:

⁶³ "atqui in quolibet nervo omnes illo minores continentur, non autem longiores; ergo etiam in quolibet sono omnes acutiores continentur, non autem contra graviore in acuto:" AT, 10:97, 7-11.

⁶⁴ Girolamo Fracastoro, *De sympathia et antipathia rerum* (Venice: haeredibus Iuntae, 1546), Chapter 11.

⁶⁵ I refer to Chapter 5 "De consonantiis," AT, 10:96-98, esp. 97 15 - 98 7.

⁶⁶ On this relation between experience and science, cf. Peter Dear, "Narratives, Anecdotes, and Experiments: Turning Experience into Science in the Seventeenth Century," in *The Literary Structure of Scientific Argument. Historical Studies*, ed. Peter Dear (Philadelphia: University of Pennsylvania Press, 1991), pp. 135-163.

There is no other reason why (sound in pipes) immediately reaches the octave rather than the fifth, except that the octave is the first of all the consonances, and that among all the consonances it differs the least by unison.⁶⁷

Logical evidence must now follow on from sensible evidence. The octave (2:1) is the first consonance as the binary is the first number: unison (1:1) is in fact not consonance but principle of consonances, just as the unit is not number but principle of numbers. Only the divisions of the interval of octave vis-à-vis the given undivided string produce the ratios of musical intervals, and the series thus obtained is a logical series of relations fused out with the generating principle, not a succession of parts one external to the other.⁶⁸ Deduction is thus a criterion of classification to the extent that the nature of consonances derives from their generation from the octave, like children from the common mother.⁶⁹

Identification with the object of music and its statute of mathematical discipline leads Descartes to an original deduction and classification of the consonances that radically reforms the internal structure of Zarlino's *senario*.⁷⁰ It is not just by chance that almost a century later, in his *Traité de l'harmonie* (1722), Jean-Philippe Rameau sees in Cartesian deduction the logico-mathematical expression of his own idea of *son fondamental* as the dynamic principle for the generation and classification of sounds.⁷¹ But between Cartesian *more geometrico* deduction and the age of Rameau lies modern science, which music itself played a considerable part in shaping by shifting onto a physical level the purely mathematical vision of musical quantities. The same Rameau, in works after *Traité de l'harmonie*, would have to carry out this descent into hell, drawing close to the new physico-

⁶⁷ "Neque ratio est, quare immediate ad octavam [sonus in fistulis] deveniat potius quam ad quintam vel alias [consonantias], nisi quia octava omnium [consonantiarum] prima est, & quae omnium minime differt ab unisono." AT, 10:99 3-6.

⁶⁸ Ibid., "De Octava," 101 5-8, 102-103.

⁶⁹ Plotin explains the notion of number as a rule of generation thus: "La puissance du nombre, en venant à l'existence, a divisé l'être et l'a rendu tel qu'il enfante la multiplicité": Plotin, *Traité sur les nombres. Enneade VI 6 [34]*, introduction, texte grec, traduction, commentaire et index grec par J. Bertier, L. Brisson, A. Charles, J. Pepin, H.D. Saffrey, A. Ph. Segonds (Paris: J. Vrin, 1980), p. 109.

⁷⁰ Cf. Matthew Shirlaw, *The Theory of Harmony. An Inquiry into the Natural Principles of Harmony, with an Examination of the Chief Systems of Harmony from Rameau to the Present Day* (London: Novello & Company, 1917; reprint ed., New York: Da Capo Press, 1969), pp. 57-62.

⁷¹ Jean-Philippe Rameau, *Traité de l'harmonie réduite à ses principes naturels* (Paris: J.-B.-C. Ballard, 1722; reprint ed., Genève: Slatkine, 1986), p. 5 ff.; cfr. Frédéric de Buzon, "La Réception du "Discours de la Méthode" dans les écrits théoriques de Jean-Philippe Rameau," in *Problématique et réception du "Discours de la Méthode" et des "Essais"*, ed. Henri Méchoulan (Paris: J. Vrin, 1988), pp. 277-282.

mathematical statute of musical science.⁷² The *Compendium musicae* is not yet physico-mathematics but its historical premise: in the music of Descartes a venerable intellectual tradition is rendered obsolete by an epistemological paradigm of a Renaissance mathematics.

⁷²Cf. Marie-Élisabeth Duchez, "Connaissance scientifique et représentation de la musique. Valeur épistémologique de la théorie ramiste de la basse fondamentale," in *Jean-Philippe Rameau. Colloque international organisé par la Société Rameau*, ed. Jérôme de La Gorce (Paris-Gêneve: Champion-Slatkine, 1987), pp. 385-391, and Thomas Christensen, *Rameau and Musical Thought in the Enlightenment* (Cambridge: Cambridge University Press, 1993).

THE STRUCTURE OF HARMONY IN JOHANNES KEPLER'S *HARMONICE MUNDI* (1619)*

Michael Dickreiter

The Mathematical-Speculative Conception of Music

In surveying the development of the history of western music, two different currents can be singled out in the way it is understood; they take alternate predominance but also pervade and stimulate each other. On the one hand, there is a mainly mathematical-speculative understanding that does not place its main emphasis on the sound of tones but on the rational activity of speculation. From this point of view, the quality of the sound of music stretches beyond itself and serves to realize a supramusical order and regularity. It finds fulfillment in the imitation of this intelligible order. On the other hand, there is a conception of music which, by contrast, places its emphasis on the quality of sound and aims to enquire into real music, with its laws and effects on man. In order to define Kepler's concept of music within these two main currents of musical conception better, we shall first try to clarify them.¹

The mathematical-speculative current took the form valid for the western world from the Pythagoreans, but in reality it goes back to advanced cultures much older than that. Two basic notions are characteristic of the Pythagorean conception of music: the notion of harmony and the notion of number.² Harmony represents the principle of synthesis, unity in variety, the principle of the construction of the cosmos, of order and beauty. Being based on the experience of sound, harmony denotes the supramusical, abstract, general, philosophical: "Music is the art of form par excellence, the perfect embodiment of constitution, regularity, law, *nomos*."³ Harmony reigns in the cosmos as well as in the souls of men, in the macrocosm as well as in the microcosm. Harmony is conceived by numbers; thus, everything is in harmony with number and can be interpreted by means of it. Numbers have a cosmic-metaphysical meaning⁴ with a rich symbolism. In

* From Michael Dickreiter, *Der Musiktheoretiker Johannes Kepler*, Chapter II A: Die Klassifikation der Harmonie (Bern und München: Francke Verlag, 1973), pp. 49-61.

¹ See especially Rudolf Schäfke, *Geschichte der Musikästhetik in Umrissen* (Berlin: B. Schöneberg, 1934; Tutzing: H. Schneider, 1964).

² Ibid., pp. 22ff.

³ Ibid., p. 24: "Musik ist die Formkunst schlechthin, der Inbegriff von Satzung, Gesetzlichkeit, Gesetz, *Nomos*."

⁴ Ibid., pp. 26ff.

the classical age of the Greeks, this view declines but reappears in a slightly new form in the period from around the 1st century B.C. to the end of Hellenism, viz. in musical Neopythagoreanism and Neoplatonism. The view combines with religious-mystical ideas that bring to the fore number symbolism and shift from speculation to magic; for this reason it is also called musical mysticism.

This view contrasts with a genuinely Greek creative achievement, an approach aiming at real music, which empirically establishes a causal relation between the individual stylistic elements of perceptible music, on the one hand, and certain affects and ethical dispositions, on the other hand.⁵ Music is interpreted psychologically and hermeneutically and is aimed at the empirical and at practice. The main representatives of this current are Aristotle and Aristoxenos. This conception of music is forced into the background by musical mysticism but nevertheless continues to be strongly influential. Thus, both Ptolemy⁶ and Boethius,⁷ the two most important sources in handing down ancient music theory and speculation, deal with the schools of the Pythagoreans and the Aristoxenians, which is an oft-used term for the advocates of the conception of music tied to its perceptible properties.

Due to the paramount influence of Boethius (ca. 480-524), the musical conception of the Middle Ages placed the emphasis on mathematical-metaphysical speculation. The decisive element in judging music is *ratio* (reason) rather than *sensus* (sense). In the Middle Ages the *ars musica* is part of the quadrivium, which constitutes the mathematical sciences within the Seven Liberal Arts. Thus, music is pure science; the customary, or practice, has no place in the system of the Seven Liberal Arts. It is not until the end of the Middle Ages that the reality of the perceptible properties of music come to the fore again. This development is brought about in the middle of the 13th century by the influence of the Arabic musical theory of Al-Farabi, which in turn is mediated by Gundissalinus. Henceforth, the empirical conception of music is attributed increasing importance, until it reaches its apex at the end of the 15th century. In the Renaissance, a certain balance between the speculative-mathematical and the empirical conception of music is reached. Beginning with the works of Gafurius, the majority of the writers on music call it "a science based on mathematical laws, which is conceivable by rules, represents affects in a certain way and serves to give praise to God."⁸ The speculative and the practical doctrine

⁵ Ibid., pp. 93ff.

⁶ Ptolemy, *Harmonics*.

⁷ Boethius, *De institutione musica*, Books 2 and 3.

⁸ See Martin Ruhnke, "Musica theórica (theoretica), practica, poetica," *Die Musik in Geschichte und Gegenwart* (=MGG), ed. Friedrich Blume (Kassel und Basel: Bärenreiter, 1961), 9:951.

complement each other. Even the purely practical textbooks for singing lessons stress this concept of music either by expounding some speculations about music or by explicitly mentioning their limitation to a specific purpose. Thus, as a matter of fact, Boethius' definition of *musica* is still valid in the Renaissance.⁹

While the system of *artes liberales* disintegrated as a result of the influence of Humanism outside Germany, where music came closer to rhetoric and broke away from mathematics, there the numerical musical theory still belonged to the *ars mathematica*,¹⁰ although only few mathematicians dedicated their work to this subject. However, in Zarlino music tied to numbers also still holds prominent position alongside that tied to words.¹¹ During the 17th century the mathematical treatment of music theory gained considerable attention, both on the part of the writers on music proper and on the part of mathematicians (Galileo Galilei, Thomas Salmon, Joseph Sauveur, Jacques de Billy, Claudius Franciscus de Chales, Jacques Ozanam, Johann H. Alsted, Abdias Treu, Gerhard J. Voss, and others.)¹² Any speculation about the universal validity of the laws of harmony, an after-effect of the quadrivial thinking that is particularly cultivated in the conception of music influenced by the Reformation, is always connected with the mathematical conception of music.¹³ We should never forget that Kepler also has his place in this tradition. At the beginning of the 18th century, there is still a close connection between mathematics and music (Johann A. Fokkerodt, Andreas Werckmeister, Ahle, Walther, Johann H. Buttstedt, Johann Ph. Kirnberger, Erhard Weigel, Johann A. Birnbaum, Lorenz Mizler) which finds its preliminary conclusion in Leonhard Euler's mathematical-musical speculations.¹⁴

It is quite natural for Kepler, and for most of the writers in the German Baroque as far as the concept of music is concerned, to consider the speculation about harmony a discipline of mathematics in the broadest sense. The mathematical-speculative, quadrivial conception of music is already denoted by the category of harmony when it points beyond the pure

⁹ Heinrich Hüschen, "Musik," *MGG*, 9:977.

¹⁰ Ruhnke, "Musica theorica," p. 951.

¹¹ See Hermann Zenck, "Zarlino's 'Istitutioni harmoniche' als Quelle zur Musikanschauung der Italienischen Renaissance," *Jahrbuch der Akademie der Wissenschaften in Göttingen* 12 (1929-1930): 15ff.

¹² Schäfke, *Geschichte der Musikästhetik*, pp. 288ff., and Rolf Dammann, *Der Musikbegriff im deutschen Barock* (Cologne: Arno Volk Verlag, 1967), pp. 24ff.

¹³ See Walter Blankenburg, "Die Nachwirkung der artes liberales in den reformatorischen Gebieten und deren Auflösungsprozeß," *Kongreß-Bericht Hamburg 1956* (Kassel und Basel: Bärenreiter, 1957), pp. 60ff., and Heinrich H. Eggebrecht, "Ars musica, Musikanschauung des Mittelalters und ihre Nachwirkungen," *Die Sammlung* 12 (1957): 306ff.

¹⁴ See H. R. Busch, *Leonhard Eulers Beitrag zur Musikgeschichte* (Regensburg: Bosse Verlag, 1970).

sound, as expressed in the title of Kepler's principal work on this topic, *Harmonices Mundi*. Harmony refers both to perceptible music and, in general, to the *consonance* of several quantities. For Kepler it is still beyond question that the science of harmony is a mathematical discipline, so that we almost hear about this view just incidentally, e.g. on the title page of the third book of *Harmonices Mundi*: "Philosophy encompasses many disciplines, and also Mathematics embraces many, one of which is called Harmonics...".¹⁵ In several passages Kepler expresses himself in a similar way.¹⁶ This means that for Kepler the encyclopedic system of education of the *septem artes liberales* (the seven liberal arts) is still intact. His conception of the nature of mathematics is oriented above all towards Euclid and his commentator Proklos.

The style of *Harmonices Mundi* clearly reveals its affiliation to mathematical science, too. For long stretches¹⁷ the subject matter is expounded *more mathematico*: "I will treat Harmonics, which is a mathematical matter, in Mathematical terms."¹⁸ This means that the entire construct of ideas is based on definitions and axioms, which are followed by the propositions ("propositiones"). Each proposition is based on the preceding definitions, axioms and propositions and is proved by them. Since this method was developed by Euclid in his *Elements* with exemplary clarity, it is also and more exactly called the *geometrical method*.¹⁹ Its strict application in music theory is unique in Kepler. Trede successfully translated the definitions, axioms and propositions of the 1st chapter of Book 3 of *Harmonices Mundi*, in which the musical doctrine of ratios is deduced, into a mathematical formal symbolic language.²⁰ This shows the strict application of the *geometrical method*. Beginning with Descartes this method did not only assume a methodological but also an epistemological meaning, as in Spinoza and Christian Wolff, and it strongly influenced Leibniz.²¹ However, it does not govern the whole text of *Harmonices Mundi*. In addition, there is another important stylistic element in Kepler's writing: by describing the course of his discoveries and even detours in making them, he

¹⁵ Johannes Kepler, *Harmonices Mundi Libri V*, in Kepler, *Gesammelte Werke*, ed. Max Caspar et al. (Munich: C.H. Beck, 1938-), 6:91: "Cum philosophia multas sit complexa facultates, multas et Mathematica, de una quidem hujus parte Harmonice dicta..."

¹⁶ Ibid., pp. 211, 397, 432 et *passim*.

¹⁷ Ibid., pp. 13-89, 101-120, 239-256 and 330-363.

¹⁸ Ibid., p. 432, similar p. 397: "Harmonica, rem mathematicam ego tradam Mathematicè."

¹⁹ See Wilhelm Windelband, *Lehrbuch der Geschichte der Philosophie*, ed. H. Heimsoeth (Tübingen: 1957¹⁵), pp. 339ff.; trans. J. H. Tufts, *A History of Philosophy* (Westport/Conn.: 1979).

²⁰ Kepler, *Harmonice Mundi III*, trans. H. Trede (Ostermündingen: 1936), pp. 51ff.

²¹ Windelband, *Lehrbuch der Geschichte der Philosophie*, pp. 339ff.

appears as a reflecting and speculating person.²² This procedure contrasts with the objective “geometrical method.” It nevertheless documents the significance of the reflecting and speculating subject towards his object, a feature which already anticipates much later developments in philosophy. Kepler, moreover, does not only consider himself a mathematician and the doctrine of harmony a mathematical science, but sees himself as a philosopher, and, thus, the doctrine of harmony is really a part of philosophy.²³ He adopts Proklos’ Neoplatonist view on the relation between mathematics and philosophy according to which mathematics is an indispensable propaedeutic to philosophy.²⁴

The Domain of Harmony

Harmony is one of the few notions in western history which has been given a variety of different senses that derive both from the field of science (cosmology, psychology, mathematics, ethics) and the arts.²⁵ Even within music the notion has been used in different senses,²⁶ both within the mathematical-speculative and the empirical conception of music. The multifarious senses of the notion of harmony have their origins in the writings of Plato and Aristotle where it becomes specialized and systematized. In the mathematical-speculative conception of music of the Christian West that unfolds in the quadrivium (i.e. in the mathematical disciplines of arithmetic, geometry, music and astronomy), harmony is conceived by means of the numerical ratio. In this broader sense, harmony, as based on the numerical proportion, is synonymous with *musica*—e.g. in Boethius, one of the most influential founders of this tradition;²⁷ this equation can already be found in Plato and Aristotle and, to a large extent, is still present in the treatises of the Middle Ages, which are influenced by Boethius,²⁸ in Glareanus,²⁹ and even until the 17th century, e.g. in Kircher.³⁰ In a different

²² This applies in particular to Book 5 of *Harmonice Mundi*.

²³ Kepler, *Harmonice Mundi, Apologia*, pp. 20, 374.

²⁴ Eduard Zeller, *Die Philosophie der Griechen in ihrer geschichtlichen Entwicklung* III 2.2 (Darmstadt, 1963), pp. 881ff.; English transl., New York, 1962.

²⁵ See Heinrich Hüschen, “Harmonie,” *MGG*, 5:1588ff., and “Der Harmoniebegriff im Mittelalter,” *Studium Generale* 19 (1966): 548ff.

²⁶ Hüschen, “Harmonie,” pp. 1609ff., and “Der Harmoniebegriff im Musikschritftum des Altertums und des Mittelalters,” *Kongreß-Bericht Köln 1958* (Kassel und Basel: Bärenreiter, 1959), pp. 143ff.

²⁷ Boethius, *De institutione musica* V, 1.

²⁸ Hüschen, “Harmonie,” p. 1609.

²⁹ Heinrich L. Glarean, *Dodekachordon* (Basel: per Henricum Petri, 1547; reprint ed., Hildesheim and New York: Olms, 1969), p. 1.

³⁰ See Ulf Scharlau, *Athanasius Kircher (1601-1680) als Musikschritftsteller: Ein Beitrag zur Musikanschauung des Barock* (Marburg: Görig & Weierhäuser, 1969), p. 85.

group of treatises, which go back to Cassiodorus and Isidore of Seville, the *scientia harmonica* is directed more to sound and generally denotes the succession of tones of high and deep pitch: “*Harmonica scientia est musica, quae discernit in sonis acutum et gravem*” (“Music is the science of harmony, that grasps highness and lowness in sounds”) (Cassiodorus),³¹ but also includes the numerical foundations of the tones.³²

Kepler’s concept of harmony is no less universal than that of Boethius, but differs in some important respects. In Kepler we cannot equate *harmonia* with *musica*, since he understands *musica* only in the narrow sense as confined to the sound quality.³³ To face now the question of the exact definition of the “science of harmony” in Kepler, i.e. of the “*disciplina harmonica*,” we must state that he does not give any explicit division or classification to delimit and differentiate the concept of harmony, nor does the general disposition of *Harmonices Mundi*. However, in this work we can find some remarks on its division that make it possible to reconstruct a sort of ‘ideal disposition’—as it shall be called for the sake of simplicity—which Kepler strove for but did not realize, partly for methodological reasons, partly for considerations of a fundamental nature. It will inform us about the classification of the concept of harmony. Its relation to the realized disposition of the *Harmonices Mundi* completes certain characteristics of Kepler’s concept of harmony. The ‘ideal disposition’ is more closely bound to tradition, and there are striking parallels to Boethius’s concept of *musica*. The ‘real disposition,’ in contrast, increases the value of perceptible music.

The first ‘ideal disposition’ has the following division:³⁴

1 *proportiones harmonicae in abstracto* (abstract harmonic ratios):

- a) proprietates geometricae figurarum [planarum regularium] (the geometrical properties of plane equilateral polygons);
- b) congruentiae (their suitability for being closely joined);
- c) proportiones harmonicae ex figuris (the derivation of harmonic ratios from plane geometrical figures).

2 *proportiones harmonicae in mundo* (the harmonic ratios in the world):

- a) harmonia in motibus coelestibus (the harmony in the motions of the heavens);

³¹ Martin Gerbert, *Scriptores Ecclesiastici De Musica*, 3 vols. (St. Blasien: typis San-Blasianis, 1784; reprint ed., Hildesheim & New York: 1969), 1:16.

³² See Gerard Pietzsch, *Die Klassifikation der Musik von Boetius bis Vgolino von Orvieto* (Halle: M. Niemeyer, 1929; reprint ed., Darmstadt: Wissenschaftliche Buchgesellschaft, 1968), pp. 51 ff., and Heinrich Hüsch, “Ars musica,” *MGG*, 1:700ff.

³³ Kepler, *Harmonice Mundi*, pp. 93, 209.

³⁴ *Ibid.*, p. 209.

- b) *harmonia in motibus naturae* (the harmony in the motions of nature);
- c) *harmonia vocis homini* (the harmony of the human voice, i.e. of perceptible music).

Elsewhere,³⁵ the same subject is divided somewhat obliquely:

- 1 *proportiones harmonicae in abstracto* (abstract harmonic ratios):
 - a) *de figuribus planis regularibus* (about plane regular polygons);
 - b) *de earum congruentia* (about their suitability for being closely joined);
 - c) *proportiones harmonicae ex figuris* (the derivation of harmonic ratios from plane geometrical figures).
- 2 *proportiones harmonicae in mundo* (the harmonic ratios in the world):
 - a) *opus Dei Creatoris* (the work of God the Creator);
 - b) *opus naturae sublunaris* (the work of sublunar nature);
- 3 *musica humana* (music made by men).

We must give priority to the twofold division, i.e. the first mentioned disposition, since it is confirmed in other places³⁶ and by Kepler's overall position. The threefold division, in contrast to the twofold one, stresses perceptible music, but apart from this is almost identical.

Let us now confront this with the real disposition of the *Harmonices Mundi*. Kepler divides this work into five books, each of which are in turn again, albeit not explicitly, subdivided:

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|----------------|--|
| Book 1: | <i>de figurarum regularium, quae proportiones harmonicas pariunt</i> (the regular geometrical figures which create harmonic ratios): |
| sections 1-35: | drawing up an order of rank of the sides of constructable regular polygons; |
| 36-44: | application of the expounded order of rank and characteristics to the polygons; |
| 45-50: | non-constructability problems and conclusions. |
| Book 2: | <i>de congruentia figurarum harmonicarum</i> (the suitability of harmonious figures for being closely joined): |
| sections 1-17: | drawing up an order of rank of suitability and general propositions; |
| 18-30: | application to the polygons and bodies. |

³⁵ Ibid., pp. 93.

³⁶ Ibid., pp. 104, 236.

- Book 3: *de ortu proportionum harmonicarum, deque natura & differentijs rerum ad cantum pertinentium* (the origin of harmonic ratios and the nature and differences of musical objects):
 chapters 1-15: theory of intervals, modes and keys;
 chapter 16: theory of composition.
- Book 4: *de configurationibus harmonicis radiorum sideralium in terra* (the harmonious configurations of the rays of the heavenly body on the earth):
 chapters 1-4: the nature of harmony;
 chapters 5-7: exposition of the harmonious configurations.
- Book 5: *de harmonia perfectissima motuum coelestium* (the perfect harmony in the motions of heavenly bodies):
 chapters 1-3: geometrical and astronomical introduction;
 chapters 4-10: harmony in the celestial motions.

Books 1 and 2 correspond to the ‘ideal disposition’ (1a and 2b). A deviation consists in the following sequence in two ways: first, the exposition of the harmonic ratios in the abstract (‘ideal disposition’, 1c) and the ‘*musica humana*’ (‘ideal disposition’, 2c esp. 3) in Book 3 is combined. Kepler justifies this by saying that there is no suitable vocabulary available for abstract harmonies:

Quia verò difficile est, Proportionum Harmonicarum differentias, Genera, Modosque abstrahere mente à vocibus et sonis Musicalibus; cùm non alia nobis suppetant vocabula, rebus explicandis necessaria, quàm Musica: ideò conjungendus nobis erit in hoc libro locus tertius cum quinto et ultimo, dicendumque non tantum de Proportionibus Harmonicis abstractis, sed etiam praeoccupandum hoc humanum creationis imitamentum in cantu.³⁷

Since indeed it is difficult to abstract with the mind the differences between the harmonic proportions, the genres and modes from the voices and from musical sounds, and since no other word than Music comes to the fore in order to explain these things, we shall join the third place to the fifth and last one already in this book [i.e. Book 3], speaking not only of the abstract harmonic proportions, but also taking into account this human imitation of the work of creation in [human] song.

At the same time this deviation from the ‘ideal disposition’ clearly reveals the significance of the quality of music as sound and the empirical, which in Kepler’s writings comes particularly to the fore from the year 1600. A second difference derives from the change in the parts that discuss

³⁷ Ibid., p. 93.

the harmony of celestial movements and the harmony in the nature in Books 5 and 4, in contrast to the 'ideal disposition' (2a and 2b). In this way, cosmic harmony appears at the end of the entire work, as its goal and climax: "Creationis verò coelorum opus, propter sublimitatem et incredibilitatem differendum in locum ultimum" ("Due to its incredible subtlety, however, we must place the work of the Creation of the Heavens last.")³⁸ Thus Kepler simply reverses the direction of his procedure within the manifestations of harmony: instead of starting from speculation and coming closer to the sphere of sound—as is the case in the 'ideal disposition'—he takes sound as his starting point and from there proceeds to his cosmic speculations. Hence, the real attitude of the *Harmonices Mundi* is not only a methodological compromise, but at the same time reflects some decisive features of Kepler's concept of music. As mentioned by Kepler himself,³⁹ he was influenced by the division of Ptolemy's *Harmonics*. Ptolemy, too, presents the speculation about the harmony of the cosmos at the end of his work.

The first division of harmony is twofold. The two parts correspond to the following pairs of concepts:

1 proportiones harmonicae in abstracto	proportiones harmonicae in concreto ⁴⁰
2 proportiones harmonicae in abstracto	proportiones harmonicae introductae in mundo ⁴¹
3 archetypus	res ⁴²
4 forma	materia ⁴³
5 mathematica	physica ⁴⁴
6 harmonia intellectualis	harmonia sensibilis ⁴⁵

This confrontation shows the duality of a spiritual and a material principle, as can be found in various philosophical schools. It includes the thought of the archetypal numerical regularity that manifests itself in the physical world and goes back to the Pythagoreans, as well as to the Platonic Theory of Ideas, the Aristotelian principle of *forma* and *materia* and the Neoplatonist concept of the *archetypus*.⁴⁶ Harmony is to be expounded

³⁸ Ibid., p. 93, similar p. 289ff.

³⁹ Ibid., p. 210.

⁴⁰ Ibid., p. 393.

⁴¹ Ibid., p. 209.

⁴² Ibid., p. 100.

⁴³ Ibid., p. 236.

⁴⁴ Ibid., p. 393.

⁴⁵ Ibid., p. 211.

⁴⁶ In Plotinus (*Enneads* V, 9) and the Latin Fathers "archetypus" is used in the sense of the Christian Neo-Pythagoreanism for the archetypes of being.

in the abstract and only then concretely applied. For the abstract and the concrete were as alike as the original Idea and its image:

Demonstro equidem in abstracto... sed applico demonstrata *Concretis*, id est subjectis physicis, motibus scilicet corporum. Et tamen abstracta mea, sunt *similia* illis concretis, nihil enim magis est alii simile, quam antitypus suo typo.⁴⁷

I demonstrate in the abstract... but I refer the demonstrations to *real things*, i.e. to physical objects, that is to the motions of bodies. And yet my abstract objects are *similar* to the real [objects], indeed nothing is most similar to something else than every thing to its archetype.

Kepler's *divisio* represents an original achievement. The pair of the concepts *intellectualis-sensilis* is introduced into the sphere of harmony and is the basis of the disposition of Kepler's principle work. *Mundus intellectualis* is the spiritual world which can only be conceived by reason, it corresponds to Plato's world of Ideas. Opposed to it is *mundus sensilis*, the real world of our sensory experience. It is the image of the intelligible world. What is multifarious and divided there, is combined to a unity here. Thus, we notice a substantial influence of Platonic and Neoplatonic philosophy on Kepler's concept of *harmonia*. Whereas 60 years before Zarlino consistently took as the basis of his *divisio* in his *Le Istitutioni harmoniche* (Venice 1558 and later) the Aristotelian pair of concepts *forma-materia*⁴⁸ and placed the emphasis on the practice of music, in which he was followed by Calvisius,⁴⁹ Kepler brings to the fore again the speculative doctrine of music and goes back to Plato's philosophy in his *divisio* of music. Thus, Calvisius contrasts sharply, and in a twofold way, with Kepler's speculative conception of music, which according to the classification of the time belongs to the *musica theorica*. First, this concerns the philosophical foundations: among Zarlino's successors, Calvisius is an Aristotelian and Kepler a Platonist. Calvisius treats first and foremost *musica practica*, Kepler *musica theorica*. From this point of view—but only from this one—a synopsis of both conceptions of music, as given by Pietzsch and called typical of the German conception of music around 1600,⁵⁰ seems to make sense. Thereby, however, the fundamental differences in their different points of departure are not taken into consideration.

We shall not here devote our attention to the further divisions of the field of the "proportiones harmonicae in abstracto," since this deals only

⁴⁷ Kepler, *Harmonice Mundi*, p. 393.

⁴⁸ Zenck, "Zarlino's 'Istitutioni harmoniche'," pp. 543ff.

⁴⁹ See K. Benndorf, "Sethus Calvisius als Musiktheoretiker," in *Vierteljahresschrift für Musikwissenschaft* 10 (1894): 411ff.

⁵⁰ Gerard Pietzsch, "Seth Calvisius und Johannes Kepler," *Die Musikpflege* 1 (1930/1931): 388ff.

with geometrical questions, not with those of harmony, and is thus a propaedeutics to harmony in the strictest sense which follows Euclid's *Elements*.⁵¹ In their 'ideal disposition' the "proportionones harmonicae in mundo" have a threefold distinction:

- | | |
|--|--|
| 1 "proportionones harmonicae in motibus coelestibus" | (the harmonic ratios in the motions of the heavens); |
| 2 "proportionones harmonicae in motibus naturae" | (the harmonic ratios in the motions of nature); |
| 3 "proportionones harmonicae vocis hominis" | (the harmonic ratios of the human voice). |

This classification of existing harmonies in the world reveals clear parallels with the ancient-medieval one of *musica mundana, humana, instrumentalis*, which goes back to the Pythagoreans and was passed over by Boethius.⁵² First of all there is, however, the following difference: whereas the traditional classification comprises all the spheres in which harmony is effective, Kepler interprets the spheres more narrowly: thus, they only represent three principal examples of the appearance of the harmonic ratios in the world;⁵³ there are, moreover, other spheres in which harmony is effective, but they are not discussed extensively.⁵⁴ This restriction to a few spheres of the effectiveness of harmony that was particularly inquired into and reflected upon, points to the specialization in the field of science from the time of the Renaissance, which was, after all, promoted to a considerable degree by Kepler himself. We shall briefly sketch these spheres and compare them with Boethius' conception,⁵⁵ with which Kepler was familiar, since his letters continually mention his studies of Boethius.⁵⁶

Kepler discusses the harmony of the cosmos in Book 5 of *Harmonices Mundi* under the title "De harmonia perfectissima motuum coelestium, ortuque ex iisdem eccentricitatibus, semidiametrorumque & temporum periodicorum," i.e. the most perfect harmony of celestial motions, and its origin from the same eccentricities, semi-diameters and periodic motions of the planets in their movements around the Sun. It clearly follows from

⁵¹ See Th. Peters, *Jo. Kepleri Harmonices Mundi Lib. I, ein Beitrag zur Geschichte der Mathematik*, Diss. Berlin 1940.

⁵² Pietzsch, *Die Klassifikation*, pp. 39ff.

⁵³ Kepler, *Harmonice Mundi, Apologia*, p. 105.

⁵⁴ Kepler, *Harmonice Mundi, Apologia*, pp. 186 and 231; cf. also Dickreiter, *Der Musiktheoretiker*, pp. 32ff.

⁵⁵ Cp. to the following Pietzsch, *Die Klassifikation*, p. 39, and Hüschen, "Harmonie," pp. 1594ff., which also contains further literature on this topic.

⁵⁶ Johannes Kepler, *Briefe 1599-1603*, in Kepler, *Werke*, 14:60, 74; *Briefe 1604-1607*, *Werke*, 15:238, 389 and 449; *Briefe 1607-1611*, *Werke*, 16:86, 141.

this that cosmic harmonies refer exclusively to the physical data of planetary movements, they are no longer speculation in the original sense but the harmonic interpretation of observed physical reality. In contrast, the concept of the *musica mundana* of antiquity and the Middle Ages is conceived much more broadly, it not only includes the harmony in the course of the planets but also in the course of time (seasons, months, days) and in the combination of the elements; the greatest complexity of this concept is reached once again in the 17th century in Fludd⁵⁷ and Kircher.⁵⁸ Of this restriction Kepler was perfectly conscious.⁵⁹ For the most part Kepler calls this sphere of harmony, therefore, quite concretely “harmonia motuum coelestium,” “proportiones orbium coelestium,” “harmonia coelorum,” “harmonia in coelorum motibus” or “harmonia coelestis.” The expression *musica mundana* is used only to denote the speculation that is entirely oriented towards the ancient and medieval tradition.⁶⁰ He uses “Musica coelestis” or “siderum musica” when he explicitly writes about perceived music as an imitation of the “celestial music,”⁶¹ for the word *musica* denotes perceived music.⁶²

According to Kepler, with their music men imitate the movements of the heavens and experience the same satisfaction God experienced when looking upon his work of Creation. The Creation is no longer the world of the imperfect but the perfect work of the perfect Creator:

Nihil igitur aliud sunt motus coelorum, quàm perennis quidam concentus (rationalis non vocalis) per dissonantes tensiones, veluti quasdam Syncopationes vel Cadentias (quibus homines imitantur istas dissonantias naturales) tendens in certas et praescriptas clausulas, singulas sex terminorum (veluti Vocum) iisque Notis immensitatem Temporis insigniens et distinguens; ut mirum amplius non sit, tandem inventam esse ab Homine, Creatoris sui Simiâ, rationem canendi per concentum, ignotam veteribus; ut scilicet totius Temporis mundani perpetuitatem in brevi aliqua Horae parte, per artificiosam plurium vocum symphoniam luderet, Deique Opificis complacentiam in operibus suis, suavissimo sensu voluptatis, ex hac Dei imitatrice Musicâ perceptae, quadamtenus degustaret.⁶³

⁵⁷ Robert Fludd, *Utriusque Cosmi maioris scilicet et minoris metaphysica, physica atque technica Historia* (Oppenheim : Johann Theodore de Bry, 1617-1618): “De musica mundana,” 1:75-106.

⁵⁸ Athanasius Kircher, *Musurgia Universalis*, 2 vols. (Rome: Ex Typographia Haeredum Francisci Corbelletti, 1650; reprint ed., Hildesheim: Olms, 1970).

⁵⁹ Kepler, *Harmonice Mundi, Apologia*, p. 375.

⁶⁰ Ibid.

⁶¹ Kepler, *Harmonice Mundi, Apologia*, pp. 329, 363; *Briefe 1620-1630, Werke*, 18:108; also “siderum musica,” Kepler, *Harmonice Mundi, Apologia*, p. 209.

⁶² See note 32.

⁶³ Kepler, *Harmonice Mundi, Apologia*, p. 328.

Accordingly the movements of the heavens are nothing but a certain everlasting polyphony (intelligible, not audible) with dissonant tunings, like certain synopations or cadences (wherewith men imitate these natural dissonances), which tends towards fixed and prescribed clauses—the single clauses having six terms (like voices)—and which marks out and distinguishes the immensity of time with those notes. Hence it is no longer a surprise that man, the imitator of his Creator, should finally have discovered the art of singing polyphonically [*per concentum*], which was unknown to the ancients, namely in order that he might play the everlastingness of all created time in some short part of an hour by means of an artistic concord of many voices and that he might to some extent taste the satisfaction of God the Workmaster with His own works, in that very sweet sense of delight elicited from this music which imitates God.⁶⁴

In Kepler we recognize the medieval thought of the celestial liturgy of the angels⁶⁵ in the acclamation:

Pater sancte, serva nos in consonantia dilectionis mutuae, ut simus unum, sicut et tu cum filio tuo, Domino nostro, et Spiritu sancto unum es, et sicut omnia opera tua, per suavissima consonantiarum vincula, unum fecisti: et ut ex reducta gentis tuae condordiâ, sic aedificetur corpus Ecclesiae tuae in his terris, sicuti tu ex Harmonijis coelum ipsum extruxisti.⁶⁶

Holy Father, keep us safe in the concord of our love for one another, that we may be one, just as Thou art one with Thy Son, Our Lord, and with the Holy Ghost, and just as through the sweetest bonds of harmonies Thou hast made all Thy works one; and that from the bringing of Thy people into concord the body of Thy Church may be built up in the Earth, as Thou didst erect the heavens themselves out of harmonies.⁶⁷

The second “salient example” of the harmonies in the world is discussed by Kepler in Book 4 of *Harmonices Mundi*. It is “de harmonia radiorum, ex corporibus coelestibus in terram descendentibus, eiusque effectum in natura seu anima sublunari & humana,”⁶⁸ i.e. about the astrological effect of the rays of the heavenly body on the earth’s soul and the human soul. The fundamental difference between Kepler’s harmonic doctrine of aspects and that of Ptolemy and his successors is that Kepler shifts the place of effectiveness of the rays of the heavenly body from the stars to the

⁶⁴ Kepler, *The Harmonies of the World*, transl. C. G. Wallis, in: M. Hutchins (ed.), *Ptolemy, Copernicus, Kepler* (Chicago and London, 1980), p. 1048.

⁶⁵ See Reinhold Hammerstein, *Die Musik der Engel. Untersuchungen zur Musikanschauung des Mittelalters* (Bern and Munich: Francke Verlag, 1962), pp. 20ff.; in this connection, mention should be made of the copperplate of the title of *Harmonice Mundi*, showing an angel playing a musical instrument.

⁶⁶ Kepler, *Harmonice Mundi, Apologia*, p. 331.

⁶⁷ Kepler, *Harmonies of the World*, p. 1050.

⁶⁸ Kepler, *Harmonice Mundi, Apologia*, p. 7.

earth's or human soul. Expressed by the concepts of Boethius' classification, in Kepler the musical doctrine of aspects does not belong to *musica mundana* any more but rather to *musica humana*. Thus Book 4 of *Harmonices Mundi* displays a striking link with the concept of *musica humana* without however developing in the least its complexity and multifarious layers. Here, as in the case of the "harmonia coelestis," it is rather the exemplary that governs. But is only after Kepler has freed astrology from 'evil' and 'good' aspects, from the "houses" and from the specific properties of the planets and reduced them to a simple mathematical core that he could include them in his mathematical conception of harmony.

The third part of Boethius' classification is *musica instrumentalis*, which comprises real, perceptible music; it is discussed by Kepler in Book 3. He calls only this part of the science of harmony "musica"⁶⁹ and is thus in accordance with the definition of *musica* which since the late Middle Ages increasingly comes to refer to the sound of music. Since, however, "musica" is the work of men, it is also called by Kepler "musica humana."⁷⁰ Thus, this concept is no way equivalent to the *musica humana* of Boethius. As Kepler could hardly have used this concept in the new sense without knowing the original meaning in Boethius, we must assume a conscious reinterpretation of the word, as found incidentally in earlier studies.⁷¹ In Kepler, the concept of *ars* does not mean the whole complex of *musica* as science and art, either, but is reduced to the audible properties.⁷² For music in this sense "cantus" is often used.

Let us now include other traditional classifications of music in our inquiry. Alongside Boethius' and Cassiodorus's classifications of music—the latter is irrelevant for our purposes—we have, shortly before the new millennium, a further classification that grants music a certain independence from the other sciences. We mean the division of music into *musica naturalis* and *musica artificialis* in Regino of Prüm,⁷³ thereafter also in other theoreticians. The *musica naturalis* comprises the spheres of *musica mundana* and *humana* according to Boethius as well as vocal music; *musica artificialis* denotes the instrumental music and its numerical foundations, hence also music theory. Apparently, Kepler is not acquainted with this classification,⁷⁴ and when Fludd confronts him with this pair of concepts⁷⁵ he rejects it with the explanation that the foundation of human arts is nature:

⁶⁹ See note 32.

⁷⁰ Kepler, *Harmonice Mundi, Apologia*, pp. 391, 401 *et passim*.

⁷¹ E.g. in Aurelianus Reomensis, Johannes Affligemensis, Roger Bacon and Nicolaus of Capua, cf. Pietzsch, *Die Klassifikation*, pp. 61, 71 and 118.

⁷² Kepler, *Harmonice Mundi, Apologia*, p. 236

⁷³ Cf. Pietzsch, *Die Klassifikation*, pp. 63ff.

⁷⁴ Kepler, *Harmonice Mundi, Apologia*, pp. 403ff.

⁷⁵ Robert Fludd, *Veritas Proscenium* (Frankfurt: Johann Theodore de Bry, 1621), p. 15.

Jam dudum respondi ad haec, Artificiorum humanorum fundamentum esse Naturam: imprimis in consonantiis, quibus utitur artifex, non aliud huius, aliud illius auribus placere; sed eundem consonantiarum numerum ab omnium hominum auribus aprobari, quod indicio est, naturae hoc opus esse.⁷⁶

I have already answered to these, [saying that] Nature is the foundation of the arts of men: first [it is thus] in the consonances, which the artist uses, [and which] are equally pleasant to the ears of this and to the ears of that man; but [also] the same number of consonances is approved by the ears of all men, this being evidence that it is the necessity of nature.

Here nature is the power of order, unlike, in the above disposition, the sum of earthly phenomena. Besides, Kepler's *divisio* in no way corresponds to this classification.

This is different when we come to the division of *musica* into *musica theorica* or *speculativa* and *musica practica* or *activa*. Kepler, too, subordinates himself to this division. It goes back to late antiquity (Aristides Quintilianus) and attracts again greater attention from the middle of the 13th century, after the more empirically oriented music theory of Al-Farabi had found its way into the medieval works on music.⁷⁷ For the doctrine of music in the Renaissance this division finally becomes predominant,⁷⁸ if we exclude the special status of the *musica poetica* in the writings on music of the Reformation. In Italy, particularly, these two parts of *musica* were felt to be interrelated and, hence, were treated on equal terms in the treatises. There was a different situation in Germany: here, the division was only latent, the treatises being restricted to the *musica practica*. One exception is Glareanus. Only after the year 1600 is there a revival of interest in the *musica theorica* (Sethus Calvisius, Joachim Burmeister, Johann Lippius, Heinrich Baryphonus, Abraham Bartolus, Michael Praetorius, Johannes Kepler and others), which is why it is the more sudden and lasting. Kepler thinks of himself as a theoretician:⁷⁹ he does not tackle the doctrine of composition, the actual *musica practica*, because of his ignorance and lack of practice: "Causarum una est proculdubio, cur praxin Musicae compositionis non attigerim, quod sim eius ignarus et in hoc opere inexercitatus."⁸⁰ ("One of the reasons why I did not treat the praxis of Musical composition is without doubt that I ignore this [part of music] and my lack of experience in it.") In fact, the individual books of *Harmonices Mundi* also

⁷⁶ Kepler, *Harmonice Mundi, Apologia*, p. 404; similar p. 387.

⁷⁷ Pietzsch, *Die Klassifikation*, pp. 78ff.

⁷⁸ Ruhnke, "Musica theorica."

⁷⁹ Kepler, *Harmonice Mundi, Apologia*, p. 374.

⁸⁰ Ibid., p. 392; similarly p. 185.

have a tendency towards a division into a theoretical and a practical part.⁸¹ To this corresponds the twofold division into “proportiones harmonicae in abstracto” and “in concreto” in the ‘ideal disposition.’

In conclusion, there are basically three elements that shape Kepler’s classification of the science of harmony and are unified in it: the philosophical thesis of the reflection of the sensory world by a supersensory world, the medieval classification of *musica mundana, humana, instrumentalis* and, finally, the classification of *musica theórica, practica* which Kepler adopts from contemporary music theory.

⁸¹ Cf. the disposition of the *Harmonice Mundi* above.

Transition

4 The Uses of Experience

Claude V. Palisca

Was Galileo's Father an Experimental Scientist?

Daniel P. Walker

The Expressive Value of Intervals and the Problem of the Fourth

WAS GALILEO'S FATHER AN EXPERIMENTAL SCIENTIST?*

Claude V. Palisca

Whether Vincenzo Galilei made experiments was questioned not long ago by the late D. P. Walker. Writing of Galilei's rule that the volume of pipes that produced an octave were in the proportion 8:1, Walker stated:

Here it is evident that Galilei did not do any experiments, since the pitch of a pipe is a function of its length and not of its cubic capacity.¹

It is not clear whether Walker meant to say "It is evident that *here* Galilei did not do any experiments," or what he actually wrote, namely: "*Here* it is evident that Galilei did not do any experiments." Indeed, what experiments Galilei did or did not perform is not always evident. He tended to state conclusions, saying they were based on "esperienze," rather than give the supporting data, as Marin Mersenne and others in the 17th century were to do. But it was certainly Galilei's investigative method to observe carefully through the senses and to test his theories by experiment.

At the very beginning of his *Dialogo* of 1581-82 he declares his preference for the truth of sense perception as opposed to authority in matters that involve sensory experience. In the dialogue the interlocutor Piero Strozzi says to Giovanni Bardi:

Before your Lordship begins to untie the knot of the proposed questions [concerning the nature of the diatonic practiced today], I wish in those things which sensation can reach that authority always be set aside (as Aristotle says in the Eighth Book of the *Physics*), and with it the tainted reason that contradicts any [sense] perception at all of truth. For it seems to me that those who for the sake of proving some conclusion of theirs want us to believe them purely on the basis of

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¹ Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, & Leiden: E.J. Brill, 1978), p. 24. H. Floris Cohen, *Quantifying Music* (Dordrecht: Reidel, 1984), pp. 83-85, takes the position that Galilei was an experimentalist, though a half-hearted one.

authority without adducing any further arguments are doing something ridiculous, not to say (with the Philosopher) acting like silly fools.²

Strozzi goes on to say that this kind of unquestioned deference to authority was bestowed on Pythagoras by his followers, but Strozzi does not feel that he owes it to Bardi, whom he will question freely, as is proper in the quest for the truth of things.

Galilei opts here for the evidence of the senses as against authority, but, as everyone knows, the senses are easily deceived. Later Galilei makes clear that it is not simply sense experience that is his guide but, if I read him right, experiment.

Galilei uses the word *sperienza* and *esperienza* in several ways. He declares, for example, that the fifth in the 3:2 proportion is the most perfect, sweeter than it is in any other ratio, "as I have judged by ear after many experiences [*sperienze*] (for I know no better means for attaining certitude)."³ Here it is not so much a matter of experiment as attentive observation, and the judgment is not of fact but of aesthetic satisfaction, of perfection and sweetness of sensation.

At other times *esperienza* refers specifically to experiment. For example, in denying credence to the story that Pythagoras determined that weights suspended from strings in the ratio 2:1 produced the octave, Galilei says he learned the truth by means of experiment:

In connection with [the theories of Pythagoras] I wish to point out two false opinions of which men have been persuaded by various writings and which I myself shared until I ascertained the truth by means of experiment [*esperienza*], the teacher of all things.⁴

² Vincenzo Galilei, *Dialogo della musica antica et della moderna* (Firenze: G. Marescotti, 1581), p. 2: "Prima che V. S. cominci à sciorre il nodo del dubbio proposto, desidero che in quelle cose dove arriva il senso, si lasci (come dice Arist. nell'ottavo della Fisica) sempre da parte non solo l'autorità; ma la colorata ragione che ci fusse contrario con qual si voglia apparenza di verità. perche mi pare che faccino cosa ridicola (per non dire insieme col Filosofo, da stolti) quelli che per prova di qual si sia conclusione loro, vogliono, che si creda senz'altro, alla semplice autorità; senza addurre di esse ragioni che valide siano." Trans. in Claude V. Palisca, *Humanism in Renaissance Musical Thought* (New Haven and London: Yale University Press, 1985), p. 269.

³ Vincenzo Galilei, *Discorso intorno all'opere di messer Gioseffo Zarlino da Chioggia* (Firenze: G. Marescotti, 1589), p. 117: "com'io per il mio udito dopo molte & molte sperienze (poiche con altro mezzo migliore non so potersene haver certezza) ho giudicato."

⁴ Galilei, *Discorso*, pp. 103-104: "nel qual luogo voglio avvertire due false openioni nate negli huomini, persuasi dagli scritti di alcuni, nelle quali sono stato ancor'io, di che sendomi ultimamente accertato con il mezzo dell'esperienza delle cose maestra..." Trans. by Claude Palisca in "Scientific Empiricism in Musical Thought," *Seventeenth-Century Science and the Arts*, ed. H. H. Rhys (Princeton: Princeton University Press, 1961), p. 128 [now in his *Studies in the History of Italian Music and Music Theory* (Oxford: Clarendon Press, 1994), pp. 200-235: 228].

According to the *Vocabolario della Crusca*, *sperienza* and *esperienza* are synonymous. Both can be equivalent to the Latin *experimentum* or *experientia* and they can mean either "experience" or "experiment." The context of the last quotation tells us that there Galilei intended *esperienza* to mean "experiment," for he had to perform experiments in which he measured weights to judge the falsity of the Pythagorean legend. In an experiment that many others (and I too) have validated, Galilei attached different weights to a string to vary its tension and discovered that to produce an octave, weights had to be in the proportion 4:1, not 2:1. Galilei was the first to state this rule in a publication. He could not have arrived at the conclusion otherwise than by experiment.

In another passage Galilei clearly spoke of repeated trials involving the same materials and procedures.

For among coins of the same goodness of material, of the same weight, cavity, thickness, and height, and also among little copper bells poured from the same mold, I have often found a difference of a whole tone. This same variety of the ratios of the diapason may be found also among strings of the same material, equality of length, and goodness, but of uneven thickness, when the same quantity of weight is suspended, and in other ways that I have experimented with many times [*da me piu volte sperimentate*].⁵

In his counterpoint treatise, Galilei made an important distinction between the knowledge of the senses and the knowledge gained through experiment. The senses know the external appearance of things, but through experiment we can learn about their intrinsic properties.

For the senses apprehend precisely differences in forms, colors, flavors, odors, and sounds. They know moreover the heavy from the light, the harsh and hard from the soft and tender, and other superficial accidents. But the qualities and intrinsic virtues of things, with respect to whether they are hot or cold, humid or dry, only the intellect has the faculty of judging, through becoming convinced by experiment [*persuaso dall'esperienza*] and not simply by the sense through the medium of the diversity of the forms and colors or other circumstances.⁶

⁵ Vincenzo Galilei, *A Special Discourse Concerning the Diversity of the Ratios of the Diapason*, trans. in Claude V. Palisca, *The Florentine Camerata: Documentary Studies and Translations* (New Haven and London: Yale University Press, 1988), p. 185; Italian text on p. 184.

⁶ Vincenzo Galilei, *Discorso intorno all'uso delle dissonanze*, Firenze, Biblioteca Nazionale Centrale, MS Galilei 1 fol. 120v; another version, fol. 166v, ed. Frieder Remppl, *Die Kontrapunkttraktate Vincenzo Galileis* (Cologne: Arno, 1980), p. 104

Galilei distinguishes here between the experience of superficial sensations, differences between which the senses can detect without difficulty, and the knowledge that comes from the analysis of these sensations studied in experiments in which, one assumes, a particular effect is isolated so that its cause may be determined by a process of regression. Galilei, unfortunately, did not theorize about method.

It would be appropriate to note that Galileo made a statement similar to his father's:

... I for this reason think that these flavors, odors, colors, etc., as regards the subject in which they seem to us to be resident, are nothing but pure names and reside only in the body which perceives them, so that when you take away the animal you have removed and annihilated all of these qualities. Since we have imposed particular names upon them that are different from those first and real accidents, we should always want to believe that these qualities are truly and really diverse from these first accidents.⁷

At the time Vincenzo Galilei was writing the essays from which I have quoted, his son Galileo was apparently not yet committed to the experimental method. Charles B. Schmitt has shown that in the early treatise *De motu*, completed in Pisa between 1589 and 1592 before Galileo left for Padua in 1592, he frequently used the term *experientia* but not in the sense of experiment. The term *experimentum* does not occur in these early writings, although the idea of "testing nature" is occasionally expressed in the phrase *periculum facere*.⁸

Vincenzo did describe a number of experiments. Here is an example:

If I place on a lute one gut string and one steel string and stretch them to be in unison in their way; then if, for example, I position seven frets and I pluck the open strings, or if I position twelve frets [and then pluck the open strings], they will not be in unison. It will follow necessarily that they were not in unison when I heard them with seven frets. Because if you add or take away equal parts from any two things, if before they were so close to equal that the sense could not tell the difference, they should seem so after as well.⁹

⁷ Galileo Galilei, *Il Saggiatore* (Roma: G. Mascardi, 1623), in *Le opere di Galileo Galilei*, ed. Antonio Favaro, 20 vols. (Firenze: Barbèra, 1890-1909), 6:347-348.

⁸ Charles B. Schmitt, "Experience and Experiment: A Comparison of Zabarella's View with Galileo's in *De motu*," *Studies in the Renaissance* 16 (1969): 80-138. Stillman Drake has found evidence of Galileo's use of experiment as early as 1608: "Galileo's New Science of Motion," in *Reason, Experiment, and Mysticism in the Scientific Revolution*, ed. M. L. Righini Bonelli and William R. Shea (New York: Science History Publications, 1975), p. 142.

⁹ Vincenzo Galilei, *A Special Discourse Concerning the Unison*, trans. in Palisca, *The Florentine Camerata*, pp. 203-205; Italian text on pp. 202-204.

Galilei employed the lute here not as a musical instrument but as a piece of laboratory equipment on which he placed strings of a mixture of materials and in a configuration that he would never have played upon as a lutenist. He performed various operations on these strings, such as placing first seven, then twelve frets at determinate distances from each other. He observed the results with the hearing and reported how the variable factors affected the results. The rule that the experiment demonstrates is not explicitly stated, but it is implied: strings of different material tuned to the unison will not produce unisons when the strings are plucked while stopped at the various frets. This experiment was part of a broader investigation into the nature of the unison. Galilei's experience and experiments taught him that unisons were not easy to achieve, that every variable must be controlled and minimized. Galilei did not explain why he chose to compare twelve and seven frets, but it is likely that he did so because he wanted to compare twelve frets placed in geometric proportion to yield equal temperament, and seven frets placed according to the ratios of true fifths and fourths, producing a Pythagorean tuning.

I recently set out to replicate this experiment using a lute built in the 17th century by an unknown maker, now in the Yale Collection, a gift of the University of Pennsylvania made in 1953, catalog number 4560.53.¹⁰ The present condition of the instrument required the use of some substitutions for the materials originally used by Galilei in his experiment; however, these did not affect the basic tenets of the experiment.

We discovered that a steel string (that is, a high-carbon iron such as Galilei would have used) approximating the diameter of a gut string would require so much tension to achieve an unison that it would damage the lute. So a brass string of 90% copper, twenty-six-thousandths of an inch in diameter, close to the thirty-thousandths of the diameter of the gut string, was used. The brass and gut strings were tuned in unison, but as Galilei experienced, they do not make a smooth unison.

To produce the highest notes of the octave above the open string would have required stopping the string past the fingerboard of the instrument and onto the belly of the instrument. (The octave is produced by dividing the distance of the vibrating string length—that is, between the nut and the bridge—in half.) This would have necessitated gluing frets onto the belly, something we did not want to do on a museum instrument. So we positioned just four frets, enough to demonstrate sufficiently what Galilei evidently set out to prove.

We tried to apply the “rule of eighteen” that Galilei proposed in his *Dialogo* for laying out the frets in equal temperament., This prescribes that

¹⁰ For this experiment I enlisted the help of a player of fretted string instruments, Lawrence Zbikowski (a doctoral student in music theory at Yale) and Professor Richard Rephann, Director of the Collection of Musical Instruments at Yale.

the distance of the vibrating string length be divided by eighteen. The first fret is then placed at $17/18$ ths of the distance, yielding an equal-tempered semitones above the open string. Then the distance from that fret to the bridge is divided by eighteen, and the second fret is placed at $17/18$ ths, and so forth. However we found that on this lute this method did not give a good equal temperament. Therefore we resorted to an electronic tuner ("sight-o-tuner") used by keyboard tuners to achieve equal temperament. We also found that the gut frets that we tied did not lie flat, so we used nylon string for the frets.

We replicated only the first part of the experiment Galilei described, in which the frets were laid out in equal temperament. It was clear that, though the open strings made satisfactory unisons, when the strings were stopped at each of the frets, the pitches produced were no longer in unison.

The second part of the experiment, in which the frets were supposedly measured according to the Pythagorean scale, is superfluous, since it was obvious that no matter what tuning were used, despite the best unison in the open strings, the pitches produced by stopping the strings at the frets would not be in unison.

In our experiment, after the frets were tied, we first tuned the open gut string in unison to the open metal string. The player then stopped the strings at the first fret and plucked first the gut, then the metal string. Returning to pluck the open strings to show that they were still in unison, the player then tested each of the other frets in the same way. (Given the frequency that lute strings slip out of tune, it was judicious of Galilei to return to the open string after each fret was tried.) After testing the four frets, the lutenist played the five-note chromatic scale first on the gut, then on the brass string. The scale on the brass string was outrageously out of tune.¹¹

However incompletely Galilei described this experiment, it is clear that he adequately designed an experiment to test the hypothesis that two strings of unlike material tuned to an unison will not yield unisons when stopped at frets. The results that he obtained were corroborated by our experiment. The metal we used probably magnified the difference between the pitches produced by the two strings at the frets, and this difference was proportionately greater as the distance from the nut increased. But qualitatively the results were similar.

Although Galilei did not idolize numbers or attribute to them magical qualities, as did some of his predecessors who were of the Pythagorean or Neo-Platonic persuasion, he believed very much in reducing phenomena to numerical relationships. At the beginning of *A Special Discourse Concerning the Diversity of the Ratios of the Diapason*, he promised to provide demonstrations in which measurements would be applied to the objects

¹¹ At the conference [see above, first note] a tape of the experiment was played.

studied. "There are few things that cannot be weighed, numbered, and measured," he said.¹² When studying sound, numbers must not be abstracted from the objects they measure, as Zarlino did in theorizing about the *numeri sonori*—the "sounding numbers." Thus, with respect to sounding bodies, numbers may be applied in three ways, analogous to measurements of lines, of surfaces, and of enclosed spaces (or, as he calls them, "concave bodies.") Depending on which of these categories is involved, a given set of numbers will not always attend the same consonances and dissonances. (This line of reasoning is introduced partly to counter Zarlino's fixation upon the *senario*, or the numbers 1, 2, 3, 4, 5, 6 as the only source of ratios that determine consonances.)¹³

There are three ways of obtaining a diapason or octave:

1) Through linear measurement, when a stretched string is divided into three equal parts, and first one-third, then two-thirds of the string are struck. Or through linear measurement when two strings made of the same material, having equal length, thickness, and goodness are stretched to the same tension to an unison and then one string is divided in half and that half is struck and compared to the whole other string. I have translated the term *bontà* as "goodness," because I am not sure exactly what Galilei meant. In its chemical usage, *bontà* refers to the purity of a metal and to whether the alloy is successfully made, with good ingredients. Thus the *bontà* of a precious metal depends on the proportion of that metal in the alloy. Galilei was not necessarily speaking of metal strings, however, so *bontà* probably refers to the uniformity of the material.¹⁴

2) In measurements analogous to surfaces, the octave may be obtained by hanging weights from two strings whose material, length, thickness, and goodness are equal, but in which the weights are in the ratio 4:1. (Incidentally, it should be noted that in this experiment Galilei did not use a musical instrument but hung weights to strings attached at only one end, like a pendulum.) The quadruple ratio also prevails when comparing the circumferences of pegs of a stringed instrument.¹⁵

3) The third way to obtain the octave is through concave bodies, when the volumes of the two concavities are in the octuple proportion. Two organ pipes in which both diameters and lengths are in duple proportion will sound an octave. Thus, doubling both the length and diameter will octuple the volume. Indeed, the formula for the volume of a cylinder, $V = \pi r^2 h$, will give this result. If the two cylindrical pipes are 16 and 8 feet respec-

¹² Galilei, *A Special Discourse Concerning the Diversity of the Ratios of the Diapason*, in Palisca, *The Florentine Camerata*, p. 181.

¹³ Ibid., p. 187. Galilei refers to Zarlino, *Istitutioni harmoniche*, Book 1, chapter 16, p. 27.

¹⁴ Ibid., p. 183.

¹⁵ Ibid., pp. 185-187.

tively, and the radii 6 and 3 inches, we get 4π for the larger volume and $\pi/2$ for the smaller volume, or a proportion of 8:1.

Marin Mersenne in his observations of organ pipes reported a similar result, that the volumes of two pipes an octave apart should be approximately in the ratio of 8:1.¹⁶ In modern organ-building practice the scaling of cylindrical metal pipes is somewhat different from that reported by Mersenne. The diameter is halved at the upper tenth rather than the octave, and, of course, the length is halved at the octave. George Ashdown Audsley in his *The Art of Organ Building* (1905), cites Marie-Pierre Hamel in his *Nouveau manuel complet du facteur d'orgues* (Paris, 1849) as advocating the halving of the diameter at the upper ninth rather than the octave.¹⁷

It is insufficient for two pipes to be in duple proportion, Galilei asserted (p. 195); this will give the major third of Aristoxenus (smaller than true); nor is quadruple proportion sufficient when comparing volumes, for this will sound a minor sixth. Galilei here did not specify which dimension was in duple proportion. But he must have meant diameter or width of pipes, rather than length. Because two pipes otherwise equal that are in duple proportion of length will sound approximately an octave. Mersenne also investigated the influence of diameter on pitch when other dimensions were equal. He found that a pipe twice another in diameter sounded a minor third below, though he noted that blowing the shorter pipe harder made that a major third, which agrees with Galilei's result. A pipe four times another produced a diminished seventh or major sixth. This again is not far from what Galilei observed.¹⁸ Vincenzo did not speak in this passage of the ratio of lengths, perhaps because he set out to prove that the duple ratio was not the only one that produced the octave.¹⁹ If the duple proportion were the absolute determinant, it should always produce an octave,

¹⁶ Marin Mersenne, *Harmonie Universelle* (Paris: S. Cramoisy, 1636-37; reprint ed., Paris: CNRS, 1963), Book 6, prop. 14, p. 335.

¹⁷ George Ashdown Audsley, *The Art of Organ Building II* (New York: Dodd, Mead, and Co., 1905; reprint ed., New York: Dover Publications, 1965), p. 573.

¹⁸ Mersenne, *Harmonie Universelle*, Book 6, prop. 12, pp. 331-332.

¹⁹ In another place in the *Discourse Concerning the Diapason*, pp. 189-190, Galilei apparently made a slip when he asked the question: "what sort of interval would two pipes make that have the same diameter but duple length? A major third of the intense tuning of Aristoxenus, which, in fact, is the third part of the octave, whereas if they are in quadruple proportion, they would sound a minor sixth of the same intense tuning." The question should have read: "have the same length but duple diameter." Mersenne's table corroborates Galilei's findings with respect to volume, since twice the diameter will produce twice the volume. For the major third in the 5:4 proportion the table gives the proportion of volumes as 125:64 (1.95); increasing the length slightly would make it the bigger third of the Aristoxenian system. Similarly, his ratio for the minor sixth, 8:5 (incorrectly printed as 6:5), is 512:125 (4.09). Cutting the length slightly gives Galilei's result of 4:1 for the Aristoxenian minor sixth.

whether the dimension were diameter, length, or volume. Galilei was adamant in denying this possibility.

The question I asked at the outset of this paper—Was Galileo's father an experimental scientist?—may, therefore, be answered decisively in the affirmative. He experimented with strings of various materials to determine whether an unison could be achieved between them and whether at a fixed tension and length two unison strings of different material produced unisons when stopped at equal segments of the length of the open string. He hung weights to strings of different lengths, diameters, and quality to determine what factors determined the consonance of the octave and what numerical ratios resulted from measuring each dimension when the octave was produced. He experimented with pipes of various lengths and diameters and resultant volumes to determine the ratios of these dimensions necessary to produce the octave, and inversely to discover what consonances were produced when any of the dimensions were in duple proportion. These investigations constituted more than attentive observation of natural events. They required setting up carefully structured conditions that tested the variables under examination.

Vincenzo's inquisitiveness was partly stimulated by practical problems of tuning the lute and keyboard instruments, but equally it was a quest for scientific truth in response to false allegations in the music-theoretical literature that associated particular numerical ratios absolutely and invariably with particular consonances. So not only did Vincenzo experiment, as every instrument builder and player does constantly, but he did so for the purpose of what can properly be considered scientific inquiry.

THE EXPRESSIVE VALUE OF INTERVALS AND THE PROBLEM OF THE FOURTH*

Daniel P. Walker

During the second half of the 16th and the first half of the 17th century several musical theorists dealt with the question: what intervals are suitable for expressing what emotions? Without exception, these authors divide emotions into two large contrasting classes: on the one hand, vigour, energy, joy, but also hardness, harshness, bitterness, and on the other, softness, weakness, sweetness, pity, sadness. The two groups of affective qualities vary somewhat from author to author; sometimes it is harshness that predominates in the former and sweetness in the latter, and sometimes joy in the former and sadness in the latter. But there are always two categories set in opposition one to the other, among which musical intervals, both harmonic and melodic, are distributed. The two qualities that remain constant are vigour in the first group and weakness in the second. For brevity's sake, then, I shall call the first group "vigorous" and the second "weak."

I shall deal first with melodic intervals and then with harmonic ones. The majority of theorists assume two general principles which determine the distribution of melodic intervals into the two classes of emotion: first, the opposition between rising and falling intervals; secondly, the opposition between large and small intervals. Evidently these two principles may conflict. In Mersenne's competition of 1640 everyone concerned agreed that small and descending intervals are weak, and that large and ascending ones are vigorous. But in the case of a descending, but eminently vigorous interval, such as the major sixth, it was doubtful whether it was weak because it descended or vigorous because it was large. In the case of semitones and minor thirds the principle of size overrode that of direction; these intervals are always weak, whether rising or falling—Mersenne states this explicitly in his *Harmonie Universelle* (1636): "Semitones and accidentals represent tears and groans because of their small intervals, which signify weakness; for little intervals, either ascending or descending, are like children, like old people or those who have recently had a long ill-

* From Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, and Leiden: E. J. Brill, 1978), pp. 63-80.

ness, who cannot walk with big steps, and who cover a short space in a long time.”¹

In some theories these two principles are combined in a more subtle and complicated manner. According to Nicola Vicentino, in his *L'Antica Musica ridotta alla moderna Prattica* (1555), the small intervals, semi-tones and minor thirds, are weak when rising and vigorous when falling, whereas the large intervals, tone, major third, fourth and fifth, are very vigorous when rising and very weak when falling. The terms used by Vicentino for the two groups of emotion are: *molle* and *mesto* for the weak, and *incitato* and *allegro* for the vigorous.² But in this passage, I think, his line of thought has been distorted by the wish to present a neat and symmetrical scheme of contrasts. For, when dealing elsewhere, separately, with minor and major thirds and tenths, he shows greater musical sense. Discussing the minor third, as both a melodic and a harmonic interval, he states that “its nature is very feeble, and is rather sad, and likes to descend; it will appear somewhat happy if accompanied with rapid, or very rapid movements; and when it ascends slowly, it will have the nature of a man when he is tired... this consonance is very suitable for sad words when it is prolonged.”³ Of the major third he says that it is “of a lively and happy nature, and it likes to ascend because of its liveliness.”⁴ Likewise the minor tenth is feeble (*debole*) and likes to descend, and the major is very lively (*molto viva*) and likes to ascend.⁵

Vincenzo Galilei, in the *Dialogo* of 1581, uses the principle of direction in a similar way. When criticizing the preference in modern polyphony for contrary motion of parts, he reasons thus: it is manifest

that the [parts] will express the same affect more efficaciously with similar than with contrary [motion]; and that joy and sadness, and the other passions, can be caused in the listener not only by high and low sounds, and by rapid or slow movements, but also by the different quality of the intervals, and even by the same

¹ Mersenne, *Harmonie Universelle*, 2 vols. (Paris: S. Cramoisy, 1636-37; reprint ed. 3 vols, Paris: CNRS, 1963), 2:173 (“Livres Second des Chantes,” prop. 26: “les demi-tons & dieses representent les pleurs & les gémissemens à raison de leurs petits intervalles qui signifient la foiblesse: car les petits intervalles qui se font en montant ou descendant, sont semblables aux enfans, aux vieillards & à ceux qui reviennent d’une longue maladie, qui ne peuvent cheminer à grand pas, & qui font peu de chemin en beaucoup de temps.”)

² Nicola Vicentino, *L'Antica musica ridotta alla moderna prattica* (Roma: A. Barre, 1555; reprint ed. by E. Lowinsky, Kassel: Bärenreiter, 1959), fols. 19-26.

³ Ibid., fol. 33^v: “sua natura, laquale è molto debole, et ha del mesto, et volentiera discende; Questa parerà alquanto allegra, quando sarà accompagnata dal moto veloce, & velocissimo; et quando ascenderà con il moto tardo, havrà della natura d’un huomo quando è stracco... questa consonanza servirà bene alle parole meste, stando alquanto ferma...”

⁴ Ibid., fol. 34: “è di natura vivace et allegra, et volentiera ascende per cagione della sua vivacità.”

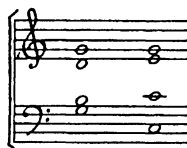
⁵ Ibid., fol. 38^v.

interval when descending or ascending. For the fifth when ascending is sad..., and when descending is joyous; and contrariwise the fourth is such when rising, and of the other quality when falling; and the same is observed to happen with the semitones and the other intervals.⁶

It is evident that in this passage Galilei is speaking of melodic intervals, since he mentions semitones, and is giving us a variation of Vicentino's theory. But elsewhere he also takes into account the harmonic progression of the parts. The reason why the fifth and fourth have opposite qualities when rising or falling is that, if these intervals make the bass of the harmony, the descending fifth or the ascending fourth produce a perfect cadence, and the contrary directions a plagal cadence:⁷



The first example, which is in an authentic mode, formed by the harmonic division of the octave, is "of a stable and tranquil nature, without violence, and suitable for inducing in the souls of the listeners grave and severe thoughts, and customs of the same kind." The second, in a plagal mode, formed by the arithmetic division of the octave, is "languid, tearful and timid."⁸ And if for the perfect cadence the mode is that which begins on C, thus:



⁶ Vincenzo Galilei, *Dialogo della musica antica et della moderna* (Firenze: G. Marescotti, 1581), p. 76: "che con maggior efficacia son'atte ad esprimere l'istesso affetto con simile, che col diverso; & che l'allegrezza & la mestitia insieme con l'altre passioni, possono esser cagionate nell'uditore non solo con il suono acuto & grave, & col veloce e tardo movimento; ma con la diversa qualità degli intervalli: anzi con l'istesso portato verso il grave, ò verso l'acuto. imperocche la quinta nell'ascendere è mesta, come detto havete, & nel discendere è lieta; & par il contrario la quarta è tale nel salire, & d'altra qualità nel discendere; & l'istesso si vede accadere al Semituono, & alli altri intervalli."

⁷ Ibid., p. 75.

⁸ Ibid., p. 74: "di natura stabile, & quieto, senza violenza, & atto à indurre negli animi degli uditori pensieri gravi & severi, & costumi da sorti"; "languida, flebile, e timorosa."

the effect will be “joyous, excited, and so to speak virile and natural;” and this effect is produced, he says, by the major third and tenth, G-B, C-e.⁹ Galilei points out that the rising tone, d-e, of the contralto is very virile (“ha grandemente del virile”), whereas the same interval, even the same notes, in a plagal cadence in the mode on D, would have a “sad and relaxed” effect (“ha del mesto & rimesso”):



And from these examples he draws the conclusion that “it is truly the bass part that in polyphony gives a song its character.”¹⁰ It is a pity that Galilei did not pursue this line further; for it is only if the harmony were taken into account that all these theories of the expressive value of melodic intervals could have any validity.

Another fruitful line of thought is that suggested by Vicentino’s remarks on the tendency of minor thirds to fall and major ones to rise. This idea is developed in a remarkable way by Kepler in the *Harmonice Mundi*. Kepler, for mathematical reasons, classed major thirds as masculine and minor ones as feminine;¹¹ but he also gives another justification for this classification. The major third is masculine because, when singing e.g. C, D, E, one feels an urge to overcome the semitone and reach the fourth, F. This third, then, is “active and full of efforts” (“actuosa et conatuum plena;”) its generative power (“vis gonimoj”) is striving to reach the fourth, and when the semitone is sung and the fourth reached this is like an ejaculation (“quaerens finem suum, scilicet Diatessaron, cujus semitonium est ei [sc. tertiae durae] quasi TMkusij, toto conatu quaesita.”) The minor third is feminine because, when singing e.g. D, E, F, one feels a tendency to sink back a semitone on to E; this third therefore is passive, and is always sinking to the ground, like a hen ready to be mounted by a cock (“semper se, veluti gallina, sternit humi, promptam inessori gallo.”)¹²

This explanation of the contrasting character of the two thirds seems to me important and fruitful because it is founded on a conception of the attractive power of the semitones, which produces in the listener the impres-

⁹ Ibid., p. 76.

¹⁰ Ibid.: “che la parte grave sia veramente quella che dà l’aria (nel cantare in consonanza) alla Cantilena.”

¹¹ [See Walker, *Studies*, chapter 4 “Kepler’s Celestial Music,” pp. 34-62].

¹² Kepler, *Gesammelte Werke*, 6: 176.

sion that certain melodic lines are likely to rise or to fall—in other terms, the conception of what was later called the leading-note. In a more general way, this conception is important because it introduces into musical theory the psychological notion of expectation, the notion that, when listening to a piece of music in a familiar idiom, one expects, at every moment, that the melody and the harmony will proceed in such or such a manner, an expectation which is often fulfilled and often disappointed.¹³

Mersenne, when discussing major and minor thirds and sixths, reproduces this theory of Kepler's, omitting of course the sexual metaphor, in order to explain why the major intervals are "very suitable for joy, and for expressing virile and courageous actions," and the minor "for flattering and for softening the passions, and for expressing sadness and pain."¹⁴ He also suggests another reason, which is perhaps valid, as a cause of this difference between the major and minor intervals. The minor sixth, he says, is "more suitable for expressing great pains and the cries that go with them; the minor third is likewise better for slighter annoyances and for flattering;" they have "this property by reason of the semitones which represents weakness, because it needs more force to sing the tone."¹⁵ In fact, a greater increase in the muscular tension of the vocal chords is required to ascend by a greater interval, and, on the other hand, to sing a descending interval produces a feeling of relaxation. This may explain why all the participants of Mersenne's competition agreed that falling intervals were suitable for expressing weakness or death, and rising ones energy and anger.

With regard to harmonic intervals, the attention of all our theorists is concentrated on the thirds and sixths, and one can see, even more clearly than with the melodic intervals, the gradual emergence of our modern modes, major and minor. With regard to their expressive value, the theorists, without exception, attribute the vigorous group to the major and the weak to the minor. Zarlino, when dealing with the imperfect consonances, describes the major ones as "lively and joyful, very sonorous" ("vive & allegre, accompagnate da molta sonorità,") and the minor, he says, "although sweet and soft, incline somewhat towards sadness or languor" ("dolci & soavi, declinano alquanto al mesto, overo languido.") On the basis of this contrast, he divides the modes into two classes according to

¹³ Cf. L. B. Meyer, *Emotion and Meaning in Music*, (Chicago: Univ. Chicago Press), 1956; and cf. Galilei on the tritone, in *Mss. Galileiani, Anteriori a Galilei*, vols. 8:1, 168^v.

¹⁴ Mersenne, *Harmonie Universelle*, 2:188 ("Livre Troisième des Genres de la Musique," prop. 18: "fort propres pour la joye, & pour exprimer les actions masles & courageuses;" "pour flater, & pour addoucir les passions, & pour exprimer la tristesse & la douleur.")

¹⁵ *Ibid.*: "plus propre pour exprimer les grandes douleurs avec des cris proportionnez, la Tierce mineure est semblablement meilleure pour exprimer les moindres déplaissirs & pour flater;" "cette propriété à raison du demiton qui represente la foiblesse, parce qu'il faut plus de force pour faire le ton." Cf. *ibid.*, "Livre Premier Des Consonances," prop. 32, p. 80.

whether there is a major or a minor third on the final: the modes on C, F, G, are “very joyful and lively” whereas those on D, E, A, are rather sad. Since the complete chords, the triads, of the two classes both contain a major and a minor third, Zarlino, like Galilei, explains this contrast by his numerical theory of consonance: the major triads are more vigorous than the minor because they are formed by the harmonic division of the fifth (15, 12, 10), which is more natural than the arithmetic division (6, 5, 4), which produces the minor triad.¹⁶

When he gives advice on the musical expression of the text Zarlino considers both melodic and harmonic intervals. He begins with a rather different version of our two classes of emotion: first, harshness, hardness, cruelty, bitterness (“asprezza, durezza, crudeltà, amaritudine”); second, complaint, pain, lamentation, sighs, tears (“pianto, dolore, cordoglio, sospiri, lagrime”). To express the first class one should use melodic intervals “without a semitones, such as the tone and major third”, and harmonic intervals such as the major sixth and major thirteenth, “which by their nature are rather harsh” when the lower note is the bass of the chord (i.e. in modern terms, a minor $\frac{6}{3}$ chord), and to which one should add suspensions of the fourth or eleventh (i.e. a major $\frac{6}{4}$ chord); in general the harmony should be “rather hard and harsh, but of such a kind, however, that it does not offend,” and suspensions of the seventh are recommended. For the second class one should use as melodic intervals “the semitones, minor third and suchlike,” and as harmonic intervals minor sixths and minor thirteenths on the bass of the chord (i.e. major/minor $\frac{6}{3}$ or minor $\frac{6}{4}$ chords), “which by their nature are soft and sweet;” in general the harmony should be full of sadness.¹⁷

Later, in the *Annotazioni* of Giambattista Doni, published in 1640, the concentration on thirds and sixths as the principal sources of affective expression becomes explicit. It is from the imperfect consonances, says Doni, that are derived “energy and efficacy in moving the effects, because the minor consonances are tearful and sad, and give this character to the chords; and the opposite is true of the major, which are joyful and spirited.”¹⁸ Doni makes this statement because he wishes to prove that the music of the ancients was polyphonic. Without thirds and sixths how could the ancient Greeks have made their songs “as pathetic and efficacious” as

¹⁶ Gioseffo Zarlino, *Istitutioni Harmoniche* (Venezia: F. de Franceschi, 1573), Part III, cahpter 10, p. 182; cf. Matthew Shirlaw, *The Theory of Harmony* (London: Novello & Coampny, 1917; reprint ed., New York: Da Capo Press, 1969), pp. 44-45.

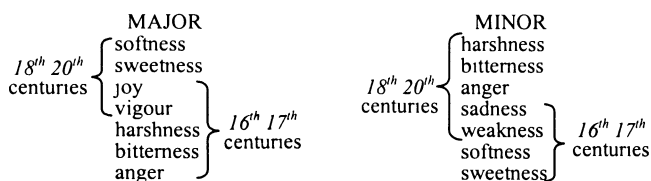
¹⁷ Zarlino, *Istitutioni*, Part IV, chapter 32, pp. 319-321.

¹⁸ Giovambattista Doni, *Annotazioni sopra il Compendio de' Generi, e de' Modi della Musica* (Roma: nella stamperia d'Andrea Fai, 1640), p. 264: “l'energia, & efficacia in muovere gl'effetti: perche le consonanze minori sono flebili, & meste; & tali rendono i concenti; & per il contrario le maggiori; che sono allegre, & spiritose.”

the witness of the most weighty authors lead us to believe?¹⁹ The Pythagoreans had banished these consonances because of their superstitious reverence for the tetractys, which stopped the series of consonances at the fourth, and which even made them deaf to the evident sweetness of the major third, to which consonance, says Doni, would well apply what Galileo Galilei had written of the fifth as compared with the octave—that “it kisses and bites us at the same time.”²⁰

A few years before this work of Doni, Mersenne, in the *Harmonie Universelle*, had reproduced, almost word for word, Zarlino’s advice for expressing the two classes of emotions. For him the modes which correspond to our major express “rigour, harshness, bitterness and anger”, and those which correspond to the minor “complaints, pain and sighs.”²¹

I want now to compare these two groups of emotions, such as we have found them in the theorists of the 16th and 17th centuries, with the emotions that a modern musician, or even an 18th century one, would attribute to our major and minor modes. I am well aware that this is a very delicate task and that the following comparative scheme is much too simple and crude to represent adequately psychological phenomena which are very subtle and variable. But nevertheless this comparison ought to be attempted because there are, I believe, important differences between the groups of the past and those of today, and if we are unaware of these differences we run the risk of wrongly interpreting the intentions of Renaissance composers and the reactions of their audiences. Here then are two lists of emotions; if on these lists one indicates by brackets the emotions that were formerly attributed to the major and minor modes and those that have been attributed to them since the 18th century, one finds that the brackets overlap in the middle, but that at both ends there is a symmetrical contrast:



The resemblance to one of Lévi-Strauss’s schemes is purely accidental—but I am very conscious that mine is too simple and too symmetrical. To convince himself that I am not wholly wrong with regard to modern re-

¹⁹ Ibid., pp. 265-6.

²⁰ Galileo Galilei, *Discorsi e dimostrazioni matematiche intorno à due nuove scienze* (Leida: Elzeviri, 1638) in *Le Opere*, ed. A. Favaro, 20 vols (Florence: Barbèra, 1890-1909), 8:149.

²¹ Mersenne, *Harm. Univ.*, V de la Composition, Pr. x, p. 323^v: “la rigueur l’âpreté, l’amertume & la cholere”; “les plaintes, la douleur, & les soupirs”. Cf. *Embellissement des Chants*, Pr. vii, p. 360.

actions to the modes, the reader has only to look through Schubert's *Winterreise* while paying attention to the verbal text and the contrasts between major and minor.

Of all the harmonic intervals only the fourth raised for theorists of our period special difficulties that were almost insurmountable, because it seemed to be both a consonance and a dissonance, two classes which were otherwise exclusive. According to either of the two theories of consonance current at this time, the arithmetic theory based on the *senario*, and harmonic proportion, or the theory based on the coincidence of vibrations, the fourth was undeniably consonant. Its ratio, 4:3, is superparticular and is contained within the numbers 1 to 6; its vibrations coincide more frequently than those of thirds and sixths. But, since the beginning of the 16th century, all composers treated the $\frac{6}{4}$ chord (the term is anachronistic, but in fact this is the chord in question) as if it were dissonant, that is to say, the note which makes a fourth against the bass must be prepared, be a suspension, and must be resolved downwards by step; the rule concerning resolution remained in force until the nineteenth century. There is a real problem here, to which no satisfactory solution has yet been found. For without doubt this chord is sweeter than a $\frac{6}{3}$, which has always been accepted as consonant. According to Helmholtz's theory, based on beats, a major $\frac{6}{4}$ is not only more harmonious than a major $\frac{6}{3}$ or a minor $\frac{5}{3}$, but even than a major $\frac{5}{3}$.²²

The majority of theorists accept, more or less reluctantly, the practical rule which demands that the $\frac{6}{4}$ be treated as dissonant, and make desperate attempts to justify this anomaly. Salinas, for example, in his *De Musica* (1577), begins by expounding the reasons in favour of the fourth: the authority of the ancients; the fact that it becomes consonant if it has a fifth under it, whereas no true dissonance can be turned into a consonance in this way; his own experience when he was at Naples, where he often heard the Greeks singing canticles with the fourth in the bass, and the effect was excellent ("& mirabiliter audiendo delectabar"); the example of Josquin des Prés who, in the mass *L'homme armé*, began the two-voice *Et resurrexit* with a fourth; the use of the $\frac{6}{4}$ on several instruments, such as the (?) guitar ("psalterium"). But then he justifies the practical rule by this rather feeble argument: since the fourth, resulting from the arithmetic division of the octave, is less perfect than the fifth, resulting from the harmonic division, it likes to be accompanied by the latter; as the vine is to the elm, or woman to man, so is the fourth to the fifth.²³ In another chapter Salinas puts forward a new classification of consonances according to which the

²² See Shirlaw, *The Theory*, p. 171.

²³ Francisco Salinas, *De musica* (Salamanca: M. Gastius, 1577), pp. 55-56.

fourth would be in the same class as the minor third and the sixths: the perfect consonances are those that can be the final chord in a two-voice piece: octave, fifth, major third; the imperfect consonances cannot be: fourth, minor third, the sixths. The perfect consonances can be harmonically divided into two consonances or two melodic intervals; the imperfect cannot be so divided.²⁴

But there was also a minority of theorists who dared, more or less timidly, to recommend the use of the $\frac{6}{4}$ as a consonance. Among this minority one is surprised to find Zarlino. Like Salinas, he invokes the authority of the ancients in favour of the fourth, and the example of Josquin, and he bears independent witness to the use of the $\frac{6}{4}$ by the Greeks, whom he has heard in their church at Venice. He believes that perhaps the origin of the modern rule is the doctrine of the Pythagoreans, who accepted as consonant only superparticular and multiple ratios and therefore rejected the eleventh, 8:3.²⁵ He gives detailed advice on the use of the fourth, from which one can extract the following principles: (in modern terms) major $\frac{6}{3}$ chords and major $\frac{6}{4}$ are always good; minor $\frac{6}{3}$ and minor $\frac{6}{4}$ are less good—they have a “triste effetto.” He then firmly states that a major $\frac{6}{4}$ is pleasanter to the ear (“piu grata all’Udito”) than a major $\frac{6}{3}$. His final conclusion is that 5/3 and 6/3 chords are always acceptable, and that the fourth “can sometimes be used with the third above it [$\frac{6}{4}$], especially when the latter is major, although until now all practical musicians have thought little of this [chord]. For, if the fourth accompanied by the major third below it [minor $\frac{6}{3}$], which is not really very consonant, is tolerated, I see no reason why [the fourth] accompanied by the major third above it [major $\frac{6}{4}$] should not be tolerated, since this [chord] is truly better, as experience will always show us.”²⁶

The most intrepid defender of the fourth is Andreas Papius, who in 1581 published at Antwerp a long treatise, *De Consonantiis, seu pro Diatessaron Libri Duo*, which is in fact a defence of the $\frac{6}{4}$ as a consonant chord. Papius is well aware of the originality of his enterprise and of the

²⁴ Ibid., pp. 69-70.

²⁵ Zarlino, *Istitutioni harmoniche* (Venezia: F. de Franceschi, 1589), Part III, chapter 5, pp. 186-188.

²⁶ Ibid., pp. 302-304: “si potrà porre alle volte con la Terza nell’acuto; massimamente quando sarà la maggiore; ancora che questo dall’università dei Musici Pratici fin’hora sia stata poco considerata; percioche se l’accompagnamento della quarta con la Terza maggiore posta nel grave, che non è veramente molto consonante, è sopportata; non sò vedere ragione, perche non si dé sopportare l’accompagnamento della Terza maggiore posta nell’acuto; essendo che questo veramente è migliore, come la esperienza ce lo farà sempre vedere.”

opposition that it will arouse among professional musicians, although two composers, Jacques de Kerle and Philippe de Monte, had encouraged him to write the book.²⁷ He welcomes therefore with enthusiasm the support given him by Zarlino's authority. Having resumed the passage I have just quoted, he cries out: "in this matter he felt the force of truth, and by professing it he has deserved eternal praise."²⁸ But unfortunately Zarlino, like the others, was led astray by his wish to justify the practice of modern composers, especially that of his master, Adrian Willaert.

Papius's arguments in favour of the $\frac{6}{4}$ are on the whole not very convincing. Most of them are based on three principles, all of which are erroneous. The first supposes that the perfect consonances, octave, fifth and fourth, are pleasanter than the imperfect, and that therefore a chord C-g-c or even C-f-c is better than a major triad C-e-g.²⁹ The second supposes that a chord which forms a mathematically harmonic series is better than one that does not do so; the chord C-f-a-c (20, 15, 12, 10) is therefore superior to C-e-g-c (30, 24, 20, 15).³⁰ The third supposes that large intervals are more beautiful than small ones; C-c-g is therefore better than C-g-c.³¹ By combining these three principles Papius erects a complicated hierarchy of consonant chords, in which the $\frac{6}{4}$ occupies an honourable place. He recommends it even as the final chord of a piece,³² and so uses it himself in the trio, stuffed with $\frac{6}{4}$ chords, which he gives as an example at the end of his book.

More interesting, but not more convincing, are the experiments that Papius describes.³³ He had discovered that even well-trained musicians, when trying to sing in unison with a flute, often in fact sang an octave lower. He ordered them to sing a fifth above the lowest note of the flute, and asked them if this made a good consonance. "They praised it greatly. But, without knowing it, they had sung a fourth below." He then made the same experiment with the fourth, which these musicians rejected with contempt, though in reality they had heard a fifth. He then led them to a place where there was an echo which reflected the sounds at their true

²⁷ Papius, *De Consonantiis Seu pro Diaterasson libri duo* (Antwerp: ex off. Ch. Plantini, 1851), p. 69.

²⁸ *Ibid.*, p. 188: "qua in re vim sensit veritatis, & profitendo laudem aeternam est promeritus."

²⁹ *Ibid.*, pp. 145-146.

³⁰ *Ibid.*, pp. 115-143, 146.

³¹ *Ibid.*, pp. 147-149.

³² *Ibid.*, pp. 161, 205.

³³ *Ibid.*, p. 54. Papius also suggests a group of experiments (*ibid.*, pp. 60-5), which consist in singing a tune accompanied by parallel consonances, first perfect, then imperfect, and also by parallel and chords; that is to say, he is unwittingly reviving the *organum* and *fauxbourdon*. He claims that this is the true test of a consonance, and that perfect parallel consonances are always superior to imperfect ones.

pitch; he repeated the experiment and the musicians reversed their judgments.

It is difficult to see what these experiments are meant to prove, since, in the first of them, the musicians did in fact, subjectively, hear the flute an octave lower. But it remains true that it is easy to confuse octaves with unisons, and fifths with fourths. This argument is also put forward by the Dutch mathematician Simon Stevin, another very original theorist and defender of the fourth.³⁴

Mersenne reproduces most of the arguments of the 16th century theorists for and against the $\frac{6}{4}$; and he confirms, by his own observations, that it is easy to mistake a fifth for a fourth and *vice versa*.³⁵ But his general intention is to justify the practical rule, although he gives a “fantaisie en faveur de la quarte,”³⁶ which in fact does not contain many $\frac{6}{4}$ s. Doni, who also has studied Zarlino, Salinas and Papius on this question, is a little less conservative. He accepts Zarlino’s opinion that a major $\frac{6}{4}$ is more harmonious than a minor $\frac{6}{3}$, and points out that in the music played on several instruments, such as the lira da braccio and the guitar, one hears the $\frac{6}{4}$ “con gran sodisfattione dell’udito.” He is therefore surprised that modern composers will not admit this chord as consonant, and he does not believe that it should always be prepared and approached by step. But he confesses that there is “qualche durezza” if the $\frac{6}{4}$ is approached by leap; in this case it could be used to express harsh and hard words. He introduces into the argument the phenomenon of beats; which is very rare at this period. If one plays a dissonance on two organ pipes, “one hears a certain beating of sounds that is unpleasant to the ear” (“si sente certo ribattimento de suoni spiacevole all’udito”); one can make the same observation with a lute, if one puts one’s ear near the table. The fourth does not produce this phenomenon, therefore it is not dissonant. He ends by recalling the canticles of the Greeks heard by Zarlino and Salinas.³⁷

What is the connexion of all these theories with the music of this period? To what extent are they *a priori* constructions, or, on the contrary, derived by induction from the practice of great composers? In one very limited case, that of Mersenne’s competition, it is possible, as we shall see in the next chapter, to attempt an answer to these questions; but in the vast field of Renaissance vocal music, to give adequate answers would require years of research and the space of several books. All I can do here is to

³⁴ Simon Stevin, *The Principal Works*, ed. Ernst Crone et alii, 5 vols. (Amsterdam: 1955–1966), 5: 450–453.

³⁵ Mersenne, *Harmonie Universelle*, 2:70–80, “Livre Premier Des Consonances,” prop. 25–32.

³⁶ Ibid., “Livre Quatriesme de la Composition,” prop. 5, pp. 300–303.

³⁷ Doni, *Annotazioni*, pp. 257–262.

give a handful of examples as illustrations of some of the main themes of this chapter.

To show the difference between the modern conception of the affective value of the major and minor modes and that of the Renaissance, here is a song which Galilei composed specially to prove that “hardness and harshness” (“il duro & l’aspro”) can be expressed without using dissonances and to demonstrate the expressive force of false relations:³⁸

The image displays three systems of musical notation, each consisting of three staves. The top staff is a vocal line in a soprano or alto clef, the middle is a vocal line in a soprano clef, and the bottom is a lute line in a bass clef. The music is written in a 16th-century style with a key signature of one flat (B-flat) and a common time signature (C). The lyrics are in Italian.

System 1:
 Top staff: Così nel mio cantar voglio esser aspro; Come negl'atti questa bella
 Middle staff: Così
 Bottom staff: Così que - sta questa bella

System 2:
 Top staff: Pie - tra la quale ogn'hor'impetra maggior durezza piu natura
 Middle staff: bella Pietra
 Bottom staff: Pie - tra

System 3:
 Top staff: Cruda, et veste sua persona d'un diaspro.

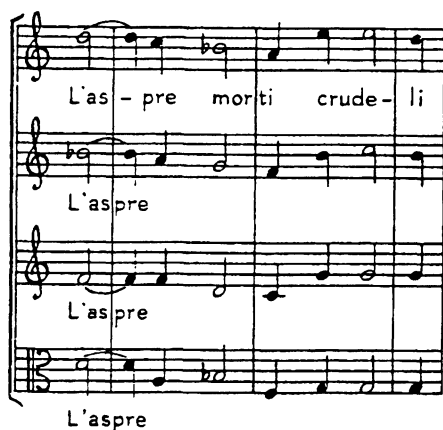
This piece contains only $\frac{5}{3}$ chords, mostly major, which, to my ear, give no impression of hardness or harshness, but produce the effect of a calm, solemn, rather mysterious hymn. There is a similar use of major $\frac{5}{3}$ chords and of chromatic progressions to express misery and horror in this passage from one of the choruses by Andrea Gabrieli for the *Edippo Tiranno*, per-

³⁸ Galilei, Mss. cit., I, 195^v-196.

formed at Vicenza in 1585, a humanist enterprise in which it was certainly intended that the music should be expressive of the text:³⁹



Even the defenders of the $\frac{6}{4}$, such as Doni and Zarlino, believed that it was suitable for expressing hardness and cruelty, and it is so used in these same choruses of Gabrieli, as, e.g. in this remarkable passage:⁴⁰



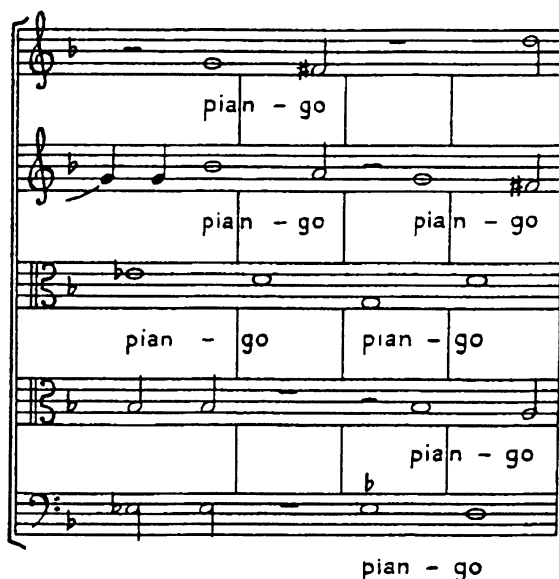
But it must be admitted that quite as often he uses major $\frac{6}{3}$ s, with the third doubled, for misery and horror, as in the passage I have just quoted.

Cipriano de Rore is the madrigalist whom the humanistic theorists cite as the supreme example of the art of expressing the text. Vincenzo Galilei

³⁹ Andrea Gabrieli, *Chori in Musica...Edippo Tiranno* (Venice: 1588) in Leo Schrade, *La Représentation d'Edippo Tiranno* (Paris: CNRS, 1960), p. 166; cf. *ibid.*, p. 222 "la cruda morte e ucciso."

⁴⁰ *Ibid.*, p. 165; cf. pp. 171 "dolenti," 182 "nocive," 191 "infelice," 197 "horror," 219 "offende;" the majority are minor $\frac{6}{4}$ s.

and Giovanni de' Bardi give lists of madrigals that they consider particularly fine in this respect.⁴¹ If one looks at these madrigals, one is indeed struck by his constant care to express the text musically. But the cases where the means employed correspond to the theories of intervals are not very numerous. Nevertheless there are a few, such as these minor $\frac{6}{4}$ s to express lamentation, which are in conformity with Zarlino's recommendations:⁴²



In the following passage the melodic and harmonic major sixths conform to the doctrine of intervals;⁴³ but one would find nothing in the theorists that would explain the beautiful false relation at "morte", or the final Neapolitan cadence:

⁴¹ For these madrigals I give in brackets the references for Cipriano Rore, *Collected Works*, ed. Bernhard Meier (Rome: American Institute for Musicology, 1961- . Bardi, "Discorso Mandato...a Giulio Caccini," in Doni, *De' Trattati di Musica*, ed. Anton Francesco Gori (Firenze: nella Stamperia Imperiale, 1763): Poiche m'invita amore (V, 78); Se bene il duolo (IV, 107); Di Virtù, di costumi (IV, 100); Un'altra volta la Germania (IV, 54); O sonno, & della quiete (IV, 66). Galilei, Mss. cit., I, 190^v: Hor che'l cielo et la terra (II, 4); Anchor che col partire (IV, 31); Cantai mentre ch'io arsi (II, 1); Come havran fin (IV, 34).

⁴² Rore, *Works*, II, 6; cf. IV, 66 "Asprezza;" II, 8 "moro."

⁴³ Ibid., IV, 80; cf. Introduction to Vol. 2, p. 5 on the use of major and minor chords to "imitar le parole."

Ex. 5

Crude - le a - cerba inesor - bil mor - te ineso -

Crude - le a - cer - ba ineso - ra - bil mor - te ineso -

Crude - le a - cer - ba inesor - bil

Crude - le a - cer - ba inesorabil

rabil mor - te Cagion mi dai di mai non ess - er lie - to

rabil mor - te Cagion mi dai cagion mi dai di mai non esser lie - to

mor - te Cagion mi dai di mai non es - ser lie - to

mor te Cagion mi dai di mai non es - ser lie - to

To express harshness and pain Cipriano very often uses a *fauxbourdon* of $\frac{6}{3}$ s, a procedure of which Theodor Kroyer has given us many other examples;⁴⁴ and this means of expressing the text is also lacking in the theorists.

If this enquiry were taken further in Cipriano's works, and those of other great madrigalists, I think that it would be found that all these theories of intervals are too simple and crude to be of much help in interpreting the music of this period. But nevertheless the groups of emotions attributed to the major and minor modes, compared with those prevalent since the 18th century, are, I think, of considerable importance and would repay further research.

⁴⁴ Theodor Kroyer, "Die threnodische Bedeutung der Quart in der Mensuralmusik," in *Bericht über den Musikwissenschaftlichen Kongress in Basel* (Leipzig: 1925), pp. 231-242.

Reassessment

5 Sound, Matter & Motion

H. Floris Cohen
Galileo Galilei

H. Floris Cohen
Isaac Beeckman

GALILEO GALILEI *

H. Floris Cohen

More than any other scientist's, Galileo's work marks the transformation from Aristotelian to modern science.¹ Though he made important contributions to a great variety of fields, such as observational astronomy, his work in mechanics above all provided the essential break-through. This applies in particular to his law of inertia (used for defending the Copernican theory,) and to his laws of free fall and projectile motion, published in 1638 in the *Discorsi e dimostrazioni matematiche intorno à due nuove scienze attenenti alla Mecanica & i Movimenti locali* ('Discourses and Mathematical Demonstrations Concerning Two New Sciences, Pertaining to Mechanics and Motion'.) To a large extent Galileo's work on moving bodies turned into a model for many other fields affected by the Scientific Revolution. It became exemplary in two essentially different, though related respects:

—it is *mathematical* in that the relationships between the parameters are quantitative, in that the proofs are geometrical, and, above all, in that the properties of falling and projected bodies are logically derived from a set of *a priori* postulates;

—it is *experimental* in that not daily experience, but nature subjected to artificial manipulation provides both the starting point and the final empirical check of the axiomatic system.

Thus Galileo's work on motion combines the defining features of the mathematical and the experimental approaches to nature. This combina-

* From H. Floris Cohen, *Quantifying Music: The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht/Boston/Lancaster: D. Reidel, 1984), pp. 85-97.

¹ The literature on Galileo is virtually boundless. A penetrating account of his work in mechanics and astronomy is given by Eduard J. Dijksterhuis, *The Mechanization of the World Picture*, trans. C. Dikshoorn (Oxford: Clarendon Press, 1961), pp. 77-123, 153-162. See also Stillman Drake in the *DSB*, and, by the same Author, *Galileo at Work. His Scientific Biography* (Chicago: University of Chicago Press, 1978). In the following I quote the *Discorsi* from a 1730 English translation: *Mathematical Discourses concerning Two New Sciences relating to Mechanicks and Local Motion*, by Thomas Weston, reprint ed. by Robert B. Lindsay, *Acoustics: History and Philosophical Developments* (Stroudsburg, Pa.: Hutchison and Ross, 1973); in the notes I give the Italian from *Le Opere di Galilei*, Edizione Nazionale a cura di A. Favaro, 20 vols. (Firenze: Barbèra, 1890-1909; reprint ed., Firenze: Barbèra, 1968):8, and add references to the standard English translation by Stillman Drake, *Galileo Galilei, Two New Sciences* (Madison, Wisc.: University of Wisconsin Press, 1974).

tion, however, occurs almost nowhere else in his work; in other fields his experimental approach is much more evident than the mathematical. This applies, for instance, to the brief passage in the *Discorsi* that is devoted to music: there is hardly a vestige of mathematization to be found in it, but it is clearly pervaded by a sense of how the manipulation of nature can reveal its hidden properties. In how far this sense corresponded to experiments carried out in reality we shall see presently.

Pendulums and Resonance

The *Discorsi* consist of four 'Days' filled with learned conversations between Salviati (Galileo's mouthpiece,) Sagredo (a mixture of second mouthpiece intelligent layman, and representative of earlier enlightened viewpoints,) and Simplicio (the Aristotelian whose lack of understanding gives occasion to explaining the issue once more in the simplest terms conceivable.) The discussion of music occurs at the end of the First Day, in the context of a discussion on pendulums. Though brief, it is packed with information.

The aim of the discussion is stated at the outset: Salviati wants "from easy and sensible Experiments, [to] deduce Reasons of the wonderful Accidents of Sounds,"² and Sagredo begs him to concentrate on the explanation of sympathetic resonance and of the consonances and their ratios. In order to do so, Salviati starts from pendulums. He states three properties of a swinging pendulum.

First, through whatever arc a given pendulum is made to swing to and fro, the duration of one complete vibration is always the same. This property (known as 'isochronism') is—wrongly—claimed to be exactly valid for any arc.

Second, the longer the pendulum, the fewer the number of vibrations per unit time, such that the lengths are inversely proportional to the squares of the numbers of vibrations. A numerical example is given that illustrates the idea, but is not intended to refer to an experiment actually performed. Here, as in many other places, Sagredo stops to marvel at such unexpected properties of nature, contradicting both daily experience and *a priori* expectation, but nevertheless true.

The third property is that every pendulum has a natural vibrational duration of its own: "it is impossible to make it vibrate in any other Period

² *Mathematical Disciplines*, p. 139; Drake, *Two New Sciences*, p. 96; *Opere*, 8:138: "se io ancora da così facili e sensate esperienze trarrò ragioni di accidenti maravigliosi in materia de i suoni..." See for a few prior remarks of Galileo's on music and acoustics his "Saggiatore," *Opere* 6:269, 280-281, 349-350.

than that which is natural to it.”³ This is demonstrated by reference to the common experience that only one definite pushing rhythm is capable of reinforcing the swinging motion of a pendulum. By carefully pushing or pulling at the proper moments (namely, precisely at the end of each complete vibration) is it possible for one man alone to raise, for instance, enormous bells.

This third property of pendulums is then invoked to explain the phenomenon of sympathetic resonance. Galileo’s explanation is quite similar to Kepler’s.⁴ He finds it on the analogy between the proper frequency of a pendulum and of a string, and then goes on to show that the vibrational pulses of a plucked string, after being transmitted through the air, tend to reinforce, and thus to sustain, the vibrational motions of another string tuned at the unison, whereas the induced vibrations of a differently tuned string are immediately dampened by lack of correspondence. Just as Kepler had done, Galileo extends the explanation to strings tuned at the octave and the fifth, thus again leaving it unclear why after the fifth dampening overtakes vibrating.

Next, the explanation of sympathetic resonance by the correspondence of vibrations is illustrated by an experiment with a glass placed in a vessel, and filled nearly to the rim with water. If with the top of a finger the rim is gently rubbed, a musical note is produced and simultaneously the water is made to undulate very regularly:

but the Tone of the Glass happening sometimes to rise an Eighth higher, I have seen at that very Instant every one of the said Waves to divide themselves into two: which Accident most plainly proves the form of the Octave to be the Double.⁵

So suddenly an illustration of resonance has turned into a demonstration of the 2:1 ratio of the octave. Walker had pointed out how questionable it is that this experiment has ever really been performed,

first because, if the vibrations of a string are too fast to be clearly seen, so will be the waves in the water, and secondly, because I have not yet succeeded in making a sounding glass jump an octave.⁶

³ *Mathematical Disciplines*, p. 142; Drake, *Two New Sciences*, p. 99; *Opere*, 8:141: “che impossibil cosa è il farlo muover sotto altro periodo che l’unico suo naturale.”

⁴ See Cohen, *Quantifying Music*, pp. 29-32.

⁵ *Mathematical Disciplines*, p. 145; Drake, *Two New Sciences*, p. 100; *Opere*, 8:143: “ed accadendo tal volta che ’l tuono del bicchiere salti un’ottava più alto, nell’istesso momento ho visto ciascheduna delle dette onde dividersi in due; accidente che molto chiaramente conclude, la forma dell’ottava esser la dupla.”

⁶ Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, and Leiden: Brill, 1978), p. 29. The first reason seems to me invalid, as

And neither have I.

Then Sagredo states with great clarity the traditional account of the ratios of the consonances as established by the monochord, and observes that this account constitutes insufficient proof for the claim that these ratios are indeed the natural ones. The arguments in favor of this contention are very similar to Vincenzo's. For "there are three Ways by which we may sharpen the Tone of a String, *viz.* by shortening it, by stretching it, or by making it thinner."⁷ The point of this is that pitch and string tension, and also pitch and string thickness, are in *squared* proportion: in order to raise pitch by an octave one should halve the length of a string, but quadruple the weight tending it, or take $\frac{1}{4}$ part of its thickness (later a correction is made in that not the thickness but rather the *weight* of a string of given length, tension, and material is said to be the relevant parameter). So should the 1:2 or rather the 1:4 ratio of the octave be considered natural?

Given the fact that the number of vibrations made by the sounding string is much too fast to be counted, it would seem that it is impossible to determine the true ratios of the musical intervals. However, two experiments solve the dilemma. The first is that of the water-filled glass already referred to in connection with the explanation of sympathetic resonance. The second is described by Salviati, who considers it even more demonstrative than the first, as here the vibrations do not last just as long as the agent operates, but are made visible on a permanent basis:

The Discovery was merely accidental... Scraping a Copper Plate with an Iron Chisel to take out some Spots in it, upon moving the Chisel quick to and fro, amongst the many Attritions or Rubbings, I, more than once, heard it send forth a whistling Noise or Sound; and then looking upon the Plate, I espied a long Row of small Streaks, parallel to one another, and exactly equidistant.⁸

It turned out that the higher the sound was made by moving the chisel faster, the closer the little lines got to each other; also the experimenter felt the chisel tremble in his hand.

Thus here, with the help of an early forerunner of the gramophone record, a method has been found to count vibrations, and, as a result, to de-

Galileo's point here is not to count the number of waves, but to show that the octave splits each wave into two.

⁷*Mathematical Disciplines*, p. 146; Drake, *Two New Sciences*, p. 101; *Opere*, 8:143: "Tre sono le maniere con le quali noi possiamo inacutire il tuono a una corda: l'una è lo scorciarla; l'altra, il tenderla più, o vogliam dir tirarla; il terzo è l'assottigliarla."

⁸*Mathematical Disciplines*, p. 148; Drake, *Two New Sciences*, p. 102; *Opere*, 8:144-145: "L'invenzione fu del caso... Raschiando con uno scarpello di ferro tagliente una piastra d'ottone per levarle alcune macchie, nel muoverti sopra lo scarpello con velocità, sentii una volta e due, tra molte strisciate, fischiare e uscirne un sibilo molto gagliardo e chiaro; e guardando sopra la piastra, veddi un lungo ordine di vergolette sottili, tra di loro parallele e per egualissimi intervalli l'una dall'altra distanti."

termine exactly the true ratios of the consonances. And lo! when the chisel was induced to give a sound of a certain pitch and then one a fifth higher (both tuned to harpsichord strings,) in the same space they produced 30 and 45 little lines, respectively, “which, indeed, is the Form attributed to the *Diapente* [Fifth].”⁹

Walker has pointed out (the first to do so in 340 years) that this famous experiment is very unlikely to have been performed in reality:

Galilei had thus discovered a means of recording musical vibrations exactly, permanently and in a form that enabled one to compare frequencies precisely. Why did no one else use it? Why has no one ever used it? Leaving on one side mechanical problems, such as what made the chisel jump so regularly, we can see that there is a flaw in the experiment, even if we accept all the facts as Galilei recounts them. He counted the spaces of the two strokes within the same distance and found the required ratio of 3:2. But on his own saying he moved the chisel faster when producing the higher note; it therefore traversed this distance in less time than the stroke producing the lower note, and, if the ratio of frequencies was 3:2, should have made less than forty-five lines compared with the lower stroke's thirty. The experiment could only possibly have produced valid results if he had compared the number of lines or spaces made during the same unit of time, not within the same distance.

One can only suppose that this was one of Galilei's so-called ‘thought-experiments’ about which he had not thought quite enough, though he tells the story with wonderfully convincing realism. I was greatly relieved to notice this mistake, since otherwise I should have had to waste a lot of time ineffectively scraping brass plates with chisels.¹⁰

The Coincidence Theory of Consonance

Having established that pitch is not only determined by the number of vibrations per unit time (or *frequency*,) but is also proportional to it, the interlocutors are now in a position to explain the phenomena of consonance and dissonance. Salviati first states the explanation in general terms:

The Offence [the Dissonances] give, proceeds, I believe, from the discordant and jarring Pulsations of two different Tones, which, without any Proportion, strike the Drum of the Ear: And the Dissonances will be extreme harsh, in case the Times of the Vibrations are incommensurable. ...Those Pairs of Sounds shall be

⁹ *Mathematical Disciplines*, p. 149; Drake, *Two New Sciences*, p. 103; *Opere*, 8:145: “quale veramente è la forma che si attribuisce alla diapente.”

¹⁰ Walker, *Studies*, p. 30. [NB. In a letter dated 4th of February, 1983, Professor Walker suggested to me that his argument does not conclusively disprove the possibility of Galileo's actually having carried out the experiment, as Galileo may have used for comparison a fifth from a harpsichord tuned in mean tone temperament.]

Consonances, and will be heard with Pleasure, which strike the *Timpanum* in some Order; which order requires, in the first Place, that the Percussions made in the same Time be commensurable in Number, that the Cartilage of the *Timpanum* or Drum may not be subject to a perpetual Torment of bending itself two different Ways, in submission to the ever disagreeing Percussion.¹¹

As a first example he discusses the octave, that (since the unison is really only one sound) is “the first and most grateful Consonance.”¹² Here every second pulse of the upper string coincides with a pulse of the lower one; something comparable is true for the fifth (3:2) and the fourth (4:3). But in the case of the whole tone (9:8) only one of nine pulses coincides, “and all the rest are Discords, and fall upon the *Timpanum* irregularly and troublesomely, and thence by the Ear are esteemed as Dissonances.”¹³

At this point Simplicio requires a more detailed exposition of the mechanism involved, which Salviati gives for the octave and the fifth. These demonstrations being exactly similar, it suffices here to summarize only the discussion of the fifth, which runs as follows. A vibration is supposed to ‘strike’ (‘percuss’) at its beginning and at its end. Now let AB represent the vibration of the string that emits the lower note, and CD the higher (see Figure 1.) AB is divided into three equal parts, and CD into two. The time needed for passing from A to E counts for one moment:

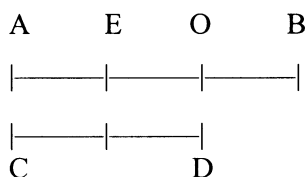


Fig. 1. From: *Discorsi*, p. 104.

¹¹ *Mathematical Disciplines*, p. 151; Drake, *Two New Sciences*, p. 104; *Opere*, 8:146-147: “La molestia di queste [sc. dissonanze] nascerà, credo io, dalle discordi pulsazioni di due diversi tuoni che sproporzionatamente colpeggiano sopra 'l nostro timpano, e crudissime saranno le dissonanze quando i tempi delle vibrazioni fossero incommensurabili... Consonanti, e con diletto ricevute, saranno quelle coppie di suoni che verranno a percuotere con qualche ordine sopra 'l timpano; il qual ordine ricerca, prima, che le percosse fatte dentro all'istesso tempo siano commensurabili di numero, acciò che la cartilagine del timpano non abbia a star in un perpetuo tormento d'infietersi in due diverse maniere per acconsentire ed ubbidire alle sempre discordi battiture.”

¹² *Mathematical Disciplines*, p. 151; Drake, *Two New Sciences*, p. 104; *Opere*, 8:147: “sarà dunque la prima e più grata consonanza l'ottava...”

¹³ *Mathematical Disciplines*, p. 152; Drake, *Two New Sciences*, p. 105; *Opere*, 8:147: “tutte l'altre sono discordi e con molestia ricevute su 'l timpano, e giudicate dissonanti dall'udito.”

After two moments the higher string strikes in D, but the lower one, having arrived in O, does not yet strike. When it does, at the third moment, in B, the other one is half-way DC, so again there is only one stroke that reaches the ear; also during this third moment the directions of the vibrations are opposite. At the fourth moment again there is only one stroke, in C, and not until six moments have passed do the strokes finally coincide; the procedure is then repeated for as long as the vibrations go on. This, Sagredo is made to exclaim, explains not only why the octave is more consonant than any other interval, but it also accounts for the peculiar nature of the fifth, which “produces such a Titillation upon the Cartilage of the *Timpanum*, that, allaying the Sweetness by a Mixture of Tartness, it seems at one and the same Time to kiss and bite.”¹⁴

Finally Salviati describes an experiment in order to demonstrate visibly what happens to the ear when struck by consonances and by dissonances; here the first two laws of the pendulum mentioned at the beginning of the previous section come in. Let three lead balls hang by strings of lengths 16 ($=4^2$), 9 ($=3^2$), and 4 ($=2^2$) respectively, and let them swing simultaneously through arbitrary arcs. Then the vibrations will coincide at every fourth vibration of the longest string, and “this Mixture of Vibrations is the same with that which being made in Strings of Instruments, presents to the Ear an *Eighth* with an intermediate *Fifth*.”¹⁵

And so, by varying the lengths of the strings, all sorts of combinations of intervals can be made visible. Thus it is confirmed that, when the ratios are incommensurable, and therefore never coincide, or when the vibrations coincide only after long intervals of time,

then the Sight is confounded by the irregular and confused Order of irregular Intermixtures, as the Ear with Regret receives the intemperate Impulses of the Air's Tremulations, which, without Order or Rule, successively strike its *Timpanum* or *Drum*.¹⁶

On this conclusion the First Day ends.

Costabel and Lerner have pointed out that this third and final experiment cannot possibly have been performed in reality. Though very con-

¹⁴ *Mathematical Disciplines*, p. 155; Drake, *Two New Sciences*, p. 107; *Opere*, 8:149: “fa una titillazione ed un solletico tale sopra la cartilagine del timpano, che temperando la dolcezza con uno spruzzo d'acrimonia, par che insieme soavemente baci e morda.”

¹⁵ *Mathematical Disciplines*, p. 156; Drake, *Two New Sciences*, p. 107; *Opere*, 8:149: “la qual mistione di vibrazioni è quella che, fatta dalle corde, rende all'udito l'ottava con la quinta in mezzo.”

¹⁶ *Mathematical Disciplines*, p. 156; Drake, *Two New Sciences*, p. 107-108; *Opere*, 8:150: “allora la vista si confonde nell'ordine disordinato di sregolata intrecciatura, e l'udito con noia riceve gli appulsi intemperati de i tremori dell'aria, che senza ordine o regola vanno a ferire su 'l timpano.”

vincing at first sight, it contains a subtle mental error: as the rates of vibration are in *inverse* squared proportionality to the lengths of the pendulums, they stand to each other not as 4:3:2, but rather as $\frac{1}{4} : \frac{1}{3} : \frac{1}{2} = 2 : \frac{8}{3} : 4$. Hence it would indeed have been possible to give the required demonstration with two lead balls hanging from strings of lengths in squared values, but not with three.¹⁷

Conclusions

The brief, 11-page passage on music summarized in the two previous sections derives its capital importance for the history of the problem of consonance from its form and style rather than its originality. Here the coincidence theory was stated briefly, compactly, authoritatively, in a brilliant and convincing style that succeeded even in hiding some of the weaker spots for more than three centuries to come.¹⁸ Together with Mersenne's work, this passage would become the starting point of all subsequent musico-scientific inquiry for at least half a century.

In this section we shall look into three aspects of Galileo's musical theory: its originality, the nature of the vibrations he posited, and the nature of the experiments he invoked in order to clarify his thought.

First, the rather involved problem of originality. Clearly the core of Galileo's musical discourse consists of the combination of ideas of Benedetti's, who had applied the vibrational nature of musical sound to the problem of consonance, and of Vincenzo Galilei's, who had shown that there is more than one type of 'natural' ratios for the consonances. As to the latter, it is fairly obvious that Galileo took the argument from his father: he shared his father's musical interest (he was himself an accomplished lutanist); he lived at home at the time Vincenzo did his experiments with strings; he inherited and preserved the latter's unpublished manuscripts; he put the argument in the mouth of Sagredo, thus more or less disclaiming priority. With Benedetti the situation is different. Though the 1585 *Diversarum speculationum... Liber* contains important adumbrations of Galileo's work on both motion and music, Galileo appears not to have known it.¹⁹

¹⁷ Marin Mersenne, *Les nouvelles pensées de Galilée* (Paris: Henry Guénon, 1638-1639), critical ed. by Pierre Costabel and Michel-Pierre Lerner, 2 vols. (Paris: J. Vrin, 1973), 2:210. Drake, *Two New Sciences*, p. 107, notes that Galileo's pupil Viviani had noticed the mistake, but apparently he corrected only the string lengths, without concluding that the experiment cannot have been performed in the way Galileo describes it.

¹⁸ Clifford A. Truesdell, "The Rational Mechanics of Flexible or Elastic Bodies 1638-1788," *Leonhardi Euleri Opera Omnia*, series 2, vol 11, sectio 2 (Zurich: Füssli, 1960), pp. 36-37, reaches the same conclusion from the acoustical point of view.

¹⁹ Cf. Drake *sub voce* 'Benedetti' in the *DSB*, pp. 607-608.

Whether or not Galileo owed much to his father and to Benedetti, he certainly handled the legacy in an independent way. As compared to Vincenzo, he carefully avoided his mistake of the cubed ratio for the intervals produced by the organ pipe; he also defined much more explicitly the functional dependence of pitch on both thickness and material (taken together as 'weight.'). Finally, he used in a more outspoken way the musical instrument as a source of experimental evidence for the musical theorist. And unlike Benedetti, Galileo at least attempted to prove the proportionality of pitch and frequency that the former had just taken for granted.

Another difference with Benedetti's account is that Galileo was much more explicit regarding the acoustical properties of the musical intervals whose frequency ratios he compared. Yet the basic notions with which they operated were the same. The production of a musical note was ascribed to a regular succession of strokes, or pulses, and their mode of propagation was compared to the classic ripples occasioned by the classic stone being thrown into the classic pond. Now it would be highly misleading to equate this particular conception of musical sound with the wave theory, according to which sounds of diverse pitches result from the regular succession of periodic condensations and rarefactions of the air, that is, from 'longitudinal waves' of diverse and definite lengths. And even though it is true that, in the course of the second half of the 17th century, the latter theory was to branch out from concepts taken from the former, they are by no means identical.²⁰ Therefore it seems better to reserve the term 'wave theory' for the latter, and to refer to the conception embraced by Galileo and his predecessors and contemporaries as the 'pulse theory of musical sound.' What both theories had in common was the idea of vibrational frequency, and the notion that this particular magnitude determines pitch. For the purpose at hand, the physical explanation of consonance, this was good enough.

Finally, we have to assess the experimental nature of Galileo's work on music. The problem whether, and if so, to what extent Galileo actually carried out the experiments he described, and, also, whether or not he *derived* his theoretical discoveries from experiment, belongs to the most heatedly debated issues in the entire history of science.²¹ There can be no question

²⁰ Cf. on these matters Sigalia Dostrovsky, "Early Vibration Theory: Physics and Music in the Seventeenth Century," *Archive for History of Exact Sciences*, 14 (1974-1975): 181-182, and Penelope M. Gouk, *Music in the Natural Philosophy of the Early Royal Society* (Ph.D. thesis, London University, Warburg Institute, 1982), chapter 1.

²¹ The two extreme positions in Alexandre Koyré, *Études Galiléennes* (Paris: Hermann, 1940) and Drake, *Galileo at Work*; see for a more moderate view Eduard J. Dijksterhuis, *Val en worp. Een bijdrage tot de geschiedenis der mechanica van Aristoteles tot Newton* (Groningen: Noordhoff, 1924), summarized in his *Mechanization of the World Picture*. See for an appraisal of the present state of the debate Michael Segre, "The Role of Experiment in Galileo's Physics," *Archive for History of Exact Sciences* 23 (1980), 3:227-252, *passim*.

of trying to resolve it here, only to add some perspective from the history of the science of music.

We have seen that, in their respective contributions to the science of music, Benedetti undertook no experiments at all, whereas those of Vincenzo Galilei were subject to some marked limitations.²² The question now is what to think of those we have just seen described by Galileo?*

In the first place he never bothered to determine experimentally quantitative values for the parameters that figured in his formulas. Just as he never tried to measure the actual acceleration rate of falling bodies, he did not attempt to determine the frequency of a specific musical note.

Secondly, none of the three musical experiments he described so vividly could have been carried out in reality, the first one (the water-filled glass) because it appears to be unrepeatable, and the two other ones for the inherent reason that they are based on mental errors. Nevertheless, there is a decisive difference with Vincenzo's mistake of the cubed ratio: while Vincenzo stated a property of nature that simply does not hold, *all three fictitious experiments of Galileo's illustrate in themselves valid propositions*. So here we have found some material that confirms a characteristic often attributed to Galileo: the incredible 'intuition', or 'sleepwalking' quality that enabled him so often to derive basically correct insights from totally wrong arguments.

So, as far as musical science is concerned, Galileo was an experimentalist in that 'artificial nature' (in this case: the musical instrument) underlay many of his theories; he was also an experimentalist in that the properties he derived from it were essentially correct; but he was not, insofar as he did no quantitative measurements, and preferred a beautiful description of an experiment to actually doing it.

The nature of the coincidence theory

So far as to Galileo's presentation of the coincidence theory. Let us pause for a moment to reflect on the extent to which the theory was capa-

²² Cohen, *Quantifying Music*, pp. 77-78, 83-85.

* [Author's note, 1998: Since on completion of *Quantifying Music* I have more or less abandoned this particular branch of scholarship, I feel compelled to refrain from subjecting the portions here selected to a critical examination or even from working into the text facts and insights offered in reviews of the book and in other recent literature. The only alteration in my original text is the somewhat rewritten paragraph to which the present note is appended. I wish further to add that I have meanwhile changed my views on Galileo's experiments in musical science on the strength of what Thomas Settle has told me about his own expert experiences with those experiments repeated, and that my sense of impressedness with pertinent facts adduced since by Claude V. Palisca shines through the two pages I devote to Vincenzo Galilei's theory and practice in my book-in-progress, 'How Modern Science Came into the World.' HFC]

ble of solving the problem of consonance. Benedetti had had hardly an idea of the explanatory power of the theory.²³ But Galileo had, and he stated it in no uncertain terms. However, the fertility of a theory depends not only on its explanatory power (as we have seen in the case of Kepler, whose theory of consonance could 'explain' all known relevant data,) but also in the encouragement it gives to look for new data, and in the new problems it raises in its turn. In this sense, the coincidence theory performed three important functions.

First of all, it implied and at the same time solved a problem that had never been stated before, namely that of providing a scale of *degrees of consonance*. Since consonance is supposed to come from the frequent coincidence of pulses it seems obvious to infer that the more often the pulses coincide the more consonant the interval in question is. Therefore a scale of degrees of consonance is given simply by multiplying the terms of the frequency ratios of the consonant intervals. As we have seen, Benedetti had indeed calculated the products, but with another, purely numerological purpose in mind. Galileo explicitly announces that his theory makes it possible to grade the consonances, but he does so only for the octave and the fifth. The complete list would have yielded the following scale (see Figure 2).

	Ratio (frequencies)	Product
[unison	1: 1	1]
octave	2: 1	2
fifth	3: 2	6
fourth	4: 3	12
major sixth	5: 3	15
major third	6: 4	20
minor third	7: 5	30
minor sixth	8: 5	40

Fig. 2

This neat table, which follows inexorably from the coincidence theory, in its turn creates a host of problems, all blissfully ignored by Galileo (who may well have neglected to draw up the table because he was aware of the new difficulties it entailed:)

—In musical practice the status of the fourth as a consonance had become rather questionable, and certainly it was considered by most musicians to be less consonant than the major third.²⁴ However, the above table

²³ Ibid., p. 78.

²⁴ Ibid., pp. 63-65.

places the fourth higher in the hierarchy of the consonances than its rival. So how to account for that?

—The order given by the table for the thirds and sixths is much more explicit than musical practice warranted. In particular, musical experience provided no reason for giving the major sixth a higher status than the major third. So, again, how to match theory and practice?

—A more fundamental objection that could be made (Galileo did not make it) is the following. If the above table is valid, the intervals represented by the frequency ratios 7:4 and 7:5 should be considered consonances as well, the former in preference even to the minor third (as $28 < 30$), the latter preceding the minor sixth (as $35 < 40$). But these intervals had always been considered as very harsh dissonances. (Kepler had succeeded in getting rid of them through the inconstructibility of the heptagon.)²⁵ For adherents of the coincidence theory there were three ways out of the dilemma: to declare it insoluble, to manipulate the table, or to pronounce the intervals with 7 to be consonances after all. Either way, they would become a touchstone for every theory of consonance, and they have remained so to this very day.²⁶

—The problem of the intervals with 7 only highlights an even more fundamental problem implicit in the coincidence theory: *there is no longer a clear-cut distinction between consonance and dissonance*. For to allow the product for the minor sixth to determine the boundary between consonance and dissonance is just as arbitrary as Zarlino's *senario*: it is as unjustified to stop at 6 (or, if need be, 8) as it is to stop at 40. The coincidence theory cannot possibly explain why the coincidence of every 8th vibration of the upper string is still perceived as pleasant, but no longer every 9th vibration. So now we can see why Kepler was to remain the only one ever to state a clear-cut scientific distinguishing criterion between consonance and dissonance: within some 10 to 20 years after *Harmonice Mundi* the distinction had become irrevocably blurred. And again, this development coincides with what happened in musical history: the new treatment of dissonance in early Baroque music instigated by, among others, Galileo's father, made obsolete any sharp theoretical distinction. In musical practice as in musical theory the boundary between consonance and dissonance had become fluid; the problem of consonance had undergone a fundamental transformation, occasioned by music and science alike.

Another important function of the coincidence theory was that it naturally gave rise to a search for hosts of new facts, such as the quantitative

²⁵ Ibid., pp. 20-21.

²⁶ M. Vogel, *Die Zahl Sieben in der spekulativen Musiktheorie* (Bonn: Ph. D. thesis, 1955) analyzes extensively the role of the intervals containing 7 in the history of musical theory; see, also, Cohen, *Quantifying Music*, pp. 103-111, and 225-228.

determination of the frequency of a musical note; the various factors that influence change of pitch; tone production in pipes and drums, and so on. In other words, *the coincidence theory of consonance became the origin of the science of acoustics*.²⁷

Finally, even apart from the many problems raised by the scale of degrees of consonance that followed from the coincidence theory, the theory itself was confronted with two very serious obstacles.

—The first, obvious as it may seem to be, was to be neglected for more than a century. Galileo had correctly observed that incommensurable terms of a ratio cause the vibrations, after the simultaneous beginning, never again to coincide. *But such is precisely the nature of all tempered intervals*. So how can we possibly perceive tempered consonances as still rather agreeable? The theory predicts that any tempering would totally destroy the consonant effect; so how to reconcile theory with practice?

—As if all this were not enough, the coincidence theory suffered from one more defect, that had been predicted by Kepler.²⁸ For what precisely was the connection between the regularity with which the eardrum was struck by the vibrations generated by the consonant intervals, and the musical beauty perceived by the human soul? Or, formulated differently, did not the coincidence theory leave completely unexplained what happens in between the eardrum being subjected ‘to a perpetual Torment of bending itself two different Ways, in Submission to the ever disagreeing Percussion’, and the experience of dissonance within us? This was the very gap that Kepler had attempted to fill by means of his theory of Sensile and Intellectual Harmony. But Galileo chose to ignore the gap, in that he apparently considered the mode of affection of the eardrum a sufficient explanation of human auditory sense experience. In doing so he left it to other scientists to find out whether the coincidence theory of consonance was able to fill the gap.

In the face of this long list of difficulties it seems a miracle that anyone aware of at least some of them had the courage to embrace the theory and pursue it further. Yet this sort of courage was vital for the Scientific Revolution. Galileo, Mersenne, and Beeckman were so impressed by what the theory could explain that they were not sufficiently deterred by what it still left open to give it up. Their insight that giving it up would be tantamount to prematurely cutting off all kinds of exciting new scientific inquiry can serve as a sign of their greatness.

Let us sum up. Zarlino’s *senario*, destroyed as a definition of the problem of consonance by Vincenzo Galilei, was, paradoxically, reinstated by the latter’s son: again the first few integers defined the ratios of the conso-

²⁷ See Cohen, *Quantifying Music*, pp. 97-114.

²⁸ *Ibid.*, pp. 31-32.

nances. However, they did so in a decisively different way. For the age-old problem could now be reformulated as follows: *why is it that the simple ratios of the vibrational frequencies of sounding bodies correspond to the human sensation of pleasure and beauty in hearing the consonant intervals?* The original question had thus undergone a striking transformation in that now an empirical physical phenomenon rather than, as before, an abstract mathematical ratio appeared to be responsible for our sense experience. In the course of the centuries the problem was to be transformed again and again; but no transformation could be so radical as the one described above: having once entered the realm of the empirical, it was never to leave it again.

ISAAC BEECKMAN*

H. Floris Cohen

The Corpuscular Theory of Sound

As all things consist of atoms of diverse forms at diverse distances from each other, that is, [distant] by intermediate empty spaces, without doubt all essential difference comes from them.¹

This sentence sums up a good deal of the fundamentals of Isaac Beeckman's (1588-1637) mechanical philosophy: all qualities of things are reduced to the motions of atoms of various shapes and sizes in the void. Beeckman was quite aware of the close link with the ancient atomic theory of Democritus and Epicurus, with which he was acquainted primarily through its poetical expression in Lucretius' *De rerum natura* ('On the nature of things'). To Beeckman the atomic theory was not the end product of a chain of scholastic reasoning on the structure of matter, but rather a fertile starting point for the explanation of the most varied aspects of nature. (It has even been hypothesized that he was the man who suggested the idea to Gassendi, the first scientist to make the atomic theory palatable for a Christian public.)²

One of the phenomena to which Beeckman applied the theory was sound. It is not quite clear whether the sound corpuscles he posited should be conceived of as atoms, for he never calls them by that name, and there are more ambiguities in his theory of matter.³ But corpuscles they were,

* From H. Floris Cohen, *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht/Boston/Lancaster: D. Reidel, 1984), pp. 120-147.

¹ Isaac Beeckman, *Journal tenu par Isaac Beeckman de 1604 à 1634* (=JIB), ed. Cornelis De Waard, 4 vols. (Den Haag: M. Nijhoff, 1939-1953), 1:201: "Cum omnes res constant atomis diversae formae diversisque à se invicem distantijs, hoc est spacijs inanibus intermedijs, procul dubio omnis differentia essentialis ab illis sumitur."

² Bernard Rochot, *Les travaux de Gassendi sur Épicure et sur l'atomisme: 1619-1658* (Paris: J. Vrin, 1944), 34 ff.

³ Cornelis De Waard, "Isaac Beeckman 1588-1637," in Eduard J. Dijksterhuis and De Waard, *Twee Nederlandsche figuren uit de zestiende en zeventiende eeuw* (Den Haag: M. Nijhof, 1941) discusses various corpuscular theories of Beeckman's (pages 302-306, 320-323, 327) without trying to make them consistent; probably they were not. In JIB 1:329 Beeckman seems to state a finite divisibility of the sound globules, but in JIB 3:56, this seems to be denied again. Also the globules do not move in the void, but rather fly through

and we shall see that they enabled Beeckman to frame one broadly coherent theory of the production as well as of the propagation and the reception of musical sound.

The corpuscular theory of sound is raised for the first time in 1616. It comes down to the idea that any vibrating object, like a string, cuts the surrounding air into little spherical corpuscles of air that are sent away in all directions by the vibrating motion of the object in question. A number of those corpuscles, on reaching the sense of hearing, constitutes together the sound heard, and thus Beeckman can say, in a formulation repeated at least ten times that to him sums up the theory: "Sound is the very same air that was in the mouth of the speaker."⁴ In fact vibration is not even a necessary condition for causing sound: whenever air is divided into little globules, sound is thereby produced.⁵

Apart from the great explanatory power of the theory, Beeckman tried to make it plausible by two independent arguments. One was a little experiment, that happened to be the same as one to be described in 1638 by Galileo, but that was used by Beeckman for drawing a quite different conclusion. It is the experiment with the water-filled glass and the finger (that according to Beeckman's specification must be somewhat moist,) rubbing in a regular movement its upper rim. Beeckman notes that the resulting sound is accompanied by regular jumps of little drops of water, as if the water was boiling, but only at the place where the rim is being rubbed. From this he concludes that the vibrating glass not only cuts little globules

the air. Moreover, under certain circumstances the globules could be broken: see the explanation of the overtones in Cohen, *Quantifying Music*, p. 127, and of overblowing, *ibidem*, p. 148. So the ambiguity remains.

⁴ For the first time in *JIB* 1:92: "Sonus est idem numero aer qui fuit in ore loquentis." The translation of 'numero' (for which the dictionary gives both 'quantitatively' and 'exactly') has given rise to some misunderstandings. Both André Pirro, *Descartes et la musique* (Paris: Fischbacher, 1907; reprint ed., Genève: Minkoff, 1977), pp. 4-5, and De Waard, *JIB* 4:177, footnote 3, translate it by 'quantitatively'; De Waard thus hopes to render the theory slightly more plausible. But to this it may be objected that (1) this translation is not compatible with Beeckman's theory, according to which the air globules that reach the ear simply are the same ones that were cut off by the vibrating string, the glottis, etc.; (2) even if this were not so, it is not clear how, if they would be something different, the quantity could possibly be the same; (3) Descartes, who knew Beeckman's theory from actual conversations with him, interpreted it as an identity rather than a numerical equality (if only to reject it contemptuously: letter to Mersenne from January 1630; *JIB* 4:177;); (4) when Beeckman states the principle in Dutch, he says, at one place, criticizing Bacon's incorporeal idea of sound: "Daerom en volcht hier niet uyt, dat (gelyck ick vooren dickwils geseydt hebbe) het geluydt niet en soude syn deselve locht, die in de mont was" (*JIB* 3:56), which means: "Therefore from this it does not follow that (as I have often said before) sound would not be the same air that was in the mouth." Similarly *JIB* 2:302.

⁵ *JIB* 4:182-183.

off the water (causing the 'boiling',) but also off the air (causing the concomitant sound.)⁶

The other confirmation is of a theoretical nature. The only mechanism by which natural phenomena can be explained is direct contact between solid bodies. Therefore a sounding body that would do nothing but *touch* the surrounding air would not be able thereby to create sound, as air is not a solid body, or at least not nearly as solid as the sounding body itself.⁷

Rejecting the Wave Theory

Beeckman's adopting a corpuscular theory of sound was not due to a failure to understand the concept of waves, or the way they are generated. In the case of the sea he even answered quite explicitly the question:

how it comes about that the water is moved, since the wind seems to press equally stiffly each part of the water?

I answer that wind, just as air, can be condensed and rarefied, that is, when it falls on the water and pushes against it, then it is compressed by the pressure of subsequent wind. This condensation and rarefaction comes about trembling, like a vibrating string. As a result the wind exerts more pressure on one part of the water than on the other, and as soon as a little groove has been made in the water it is enlarged at once, for the wind that, in the case of a smooth body, slides along the body, is now kept in the little groove and increases the pressure. ...the wave rises as long as the weight of the water of the wave is not too heavy for the force of the wind to sustain it; but the wave descends when the wind, no longer able to raise the water, relaxes and, as has been said before, is tremblingly rarefied. This is why the stronger the wind is, the higher and larger are the waves, unless the water is very shallow...⁸

⁶ The experiment is described in *JIB* 1:210; in *JIB* 3:247-248 the conclusion is drawn explicitly. Cp. *JIB* 4:159.

⁷ *JIB* 2:288.

⁸ *JIB* 2:37-38: "oe kompt, dat het water geroert wert, dewyle de wint op elck deelken des waters even styf schyndt te dringhen? Ick antwoordde, dat de wint, gelyck oock de locht, kan gedenseert ende gerarifieert werden, dat is, alse opt water valt ende daertegen stoot, so wort se door den drangh van volghenden wint ineen gedronghen. Dese densatie end rarefactie gaet al bevende toe, gelyck een snare, die davert, waerdoor het gebeurt, dat de wint op het een deelken des waters altemet meerder drangh maeckt dan op het ander; ende so haest alser een kleyn voorken in het water gemaectt is, so wort het terstondt grooter, want de wint, die op een effen lichaem lanckx het lichaem henen schuyfde, die wort nu in dat groefken gehouden ende maeckt den drangh grooter. ...de bare verheft sich so langhe totdat de swaerte van het water der bare swaerder is dan het door de kracht des wints omhooghe kan gehouden worden; maer de bare sackt neder als de wint, niet meer konnende het water verhooghen, sich relaxeert ende, gelyck vooren geseydt is, gerarifieert wort, al bevende. Daervan kompt het, hoe stercker de wint is, hoe hoogher ende grooter baren, tensy dat het water seer ondiep is..."

Thus it appears to be perfectly clear to Beeckman how successive condensations and rarefactions constitute waves, and how the amount of force exerted determines the maximal displacement; in fact he even compares the whole process with the vibrations of a string. How, then, did Beeckman succeed in *not* adopting a wave theory of sound?

The answer is that in Beeckman's view such a theory was unable to account for the propagation of sound. In his time, insofar as something like a wave theory of the propagation of sound was put forward, it was only by way of the traditional comparison with the ripples generated by a stone when thrown into quiet water. But in Beeckman's view this analogy is untenable. If it were true that sound would consist of moved air, it would be a kind of wind. And this would imply, contrary to all experience, that wind, on reaching the sense of hearing, would evoke sound. Also sound would, just like wind, affect the skin, and finally it would be impossible to explain why it is that sounds coming from different or even opposite directions hardly impede each other, whereas wind can blow only from one direction at a time.

Beeckman's objections to equating sound with wind are, of course, perfectly valid. His crucial mistake is the assumption that this identification follows from the wave analogy. It would seem that such a mistake could only be made by someone who is not aware of the fact that in the propagation of sound it is not the air itself, but only its to and fro motion that is successively passed on. But the amazing thing is that Beeckman appears to know this perfectly well, so that we are forced to attribute his rejection of the wave analogy to his *a priori* conviction that, like all other natural phenomena, such as light, sound cannot but consist of particles of matter:

when a hard body is percussed while there is air in between, or when, in whatever way the sound is generated, air is moved, the first air that has directly been moved by the percussion does not push forward the air nearest to it in order to move it in the same way it was moved itself, and again this [layer of air] the next, until finally the ears are struck by the successive motion, as we have said to happen in water, but [I say that] the very same air that is directly touched and affected by a hard thing, is [thereby] violently shocked and dispersed, and scattered particle-wise everywhere, so that the air itself that had received the impulse strikes our ear, in the way a candle flame spreads itself through space and is called *light*.⁹

⁹ *JIB* 1:92: "Dico igitur, cùm corpus durum percutitur aerque intercipitur, aut aer, quovis modo quo sonus fit, movetur, primum aerem quem percussio immediatè movet, non protrudere aerem proximum eodemque modo movere atque ipse motus erat, atque hunc iterum sibi proximum impellere dum successione aures impingantur, ut in aquâ fieri diximus, sed illum ipsum aerem, qui tangitur immediatè et afficitur a re durâ, violenter discuti, disjici et partitè se undique diffundere, ita ut ipse aer impulsus aures nostras feriat, eo modo quo flamma candelae se spargit per totam aulam et vocatur *lux*." Beeckman never gave up this view: *JIB* 4:161, 185. Cp. *JIB* 2:71-72, where he rejects superposition in the case of interpenetrating ripples from two stones thrown into the water simultaneously.

And now Beeckman has no difficulty at all in explaining why we can simultaneously hear sounds from opposite directions: owing to the great velocity of the air globules, and to the fact that they do not stream in one line but cover a certain width, it will never happen that every single globule emitted by one source collides with a globule emitted by an opposite one. And even if such an unlikely event would occur, most particles would be deflected thereby to such a small extent that they would reach the ear nevertheless.

So far about Beeckman's use of the corpuscular theory of sound as a defensive weapon against possible rival views. Next we are going to investigate what phenomena Beeckman derived from or explained with the help of this extraordinary theory. The first of these was his analysis of pitch.

Frequency and Pitch

As we have seen,¹⁰ Benedetti in 1585 had not even attempted to prove the inverse proportionality between string length and frequency, and when, in 1638, Galileo tried to prove it he could offer nothing but two pseudo-experiments.¹¹ However, in 1636 Mersenne published a geometrical proof, the discussion of which has been postponed to this chapter because he had taken it from Beeckman, who had found it in 1614-15 and communicated it to Mersenne in 1629.¹² It is the only part of Beeckman's work in music and acoustics that has received due attention in the literature, so it need only be summarized here quite briefly.¹³

The aim of the proof is to show, by a method fit for generalization of the result, that strings of lengths 1:2, thus producing the octave, vibrate in frequencies 2:1. It runs as follows (see figure 1:)

¹⁰ Cohen, *Quantifying music*, pp. 75-78.

¹¹ Ibidem, pp. 88-90.

¹² Derivation of the proof: *JIB* 1:54-55; communication to Mersenne : *JIB* 4:146; publication by Mersenne: *Harmonie Universelle* (Paris: S. Cramoisy, 1636-1637: reprint ed., 3 vols., Paris: CNRS, 1965), 1:157-158 ("Livre troisieme des mouvemens & du son des chordes," proposition 1.)

¹³ Clifford A. Truesdell, "The Rational Mechanics of Flexible or Elastic Bodies 1638-1788, in *Leonhardi Euleri Opera Omnia*, series 2, vol. 11, section 2 (Zurich: Füssli, 1960), pp. 25-26; here also a comment on the validity of the proof.

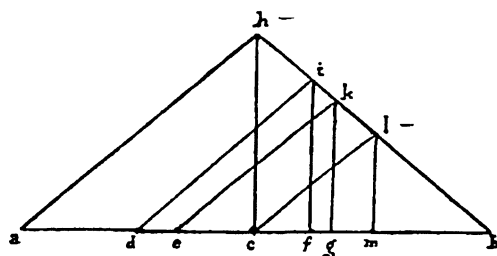


Fig. 1. From Beeckman's *Journael* (ed. by De Waard), 1:54.

A given string ab will, together with its half cb , generate an octave. If ab is such that it can be stretched as far as h , then cb can be stretched as far as l . As clb is half ahb , lm is half hc . As the whole string and its half are equally affected by the stretching, both will, upon release, return with equal force to their original places; ab and cb respectively. Their speeds thus being equal, and the distance hc being twice the distance lm , clb will pass twice through the point of departure m in the time ahb needs for passing once through c . In other words, half the string performs twice as many vibrations per unit time as the whole string, *q.e.d.*

This result is immediately generalized, first, from the octave to all musical intervals (because the proof runs similarly for any given ratio of string lengths,) and, second, from the string to all sound-producing objects. For musical sounds deriving from whatever source can be made consonant with sounds from strings, and thus pitch is proportional to frequency irrespective of the way the note is produced.

Despite these results Beeckman never bothered to determine the actual frequency of a note of given pitch. When, in 1629, Mersenne communicated to him his findings on the subject, Beeckman's first reaction was to doubt the practical usefulness of this type of inquiry:

...it never occurred to me to calculate the number itself, and this perhaps because I never saw any use in that, nor do I see it now.¹⁴

...since an infinite number of things of definite usefulness is up for inquiry, I do not see why we should fatigue ourselves with those that do not yet appear to be useful.¹⁵

¹⁴ *JIB* 4:142: "at numerum ipsum supputare, nunquam mihi in mentem venit, idque fortassis quia usum ejus rei nullum unquam vidi, nec etiam etiamnum video."

¹⁵ *JIB* 4:182: "At cum certorum usuum infinita sint quaerenda, non video cur in ijs, quorum usus nondum apparet, desudemus."

Beeckman indeed stood to his commitment to applied science: Mersenne's subsequent demonstration of the advantages of pitch standardization immediately convinced him of the legitimacy of pursuing the matter.¹⁶

Pitch, Loudness, and Tone Quality

Modern acoustical theory distinguishes between three properties of a musical note: pitch, loudness, and tone quality, the last being all the difference we perceive between two notes of equal pitch and loudness produced by different sources of musical sound, for instance, the human voice and the flourish of a trumpet. Since roughly the end of the 17th century musical sound is represented by waves, and the three distinct properties of sound are said to correspond to the three properties that can be assigned to waves, pitch being determined by the frequency of the vibrations that make up the wave, loudness by its amplitude, and tone quality by its shape (which, in its turn, represents the 'mix' of partial tones the musical note in question consists of.)¹⁷ Thus there is a simple one-to-one correspondence (see figure 2.)

Sensation		Wave theory
pitch	-	frequency
loudness	-	amplitude
tone quality	-	shape

Fig. 2

However, we have seen that the pioneers of acoustics did not conceive of the way the vibrations of the sounding object affect the air as waves, but rather as a succession of pulses. In this view the association of pitch with frequency causes no trouble: Beeckman, Mersenne, and Galileo stated it unambiguously, and both Mersenne and Beeckman explicitly cautioned not to confuse frequency with amplitude in this respect, as was still being done by Kepler.¹⁸ Thus the correspondence of loudness with amplitude had

¹⁶ *JIB* 4:158 and 182. After Mersenne's demonstration (cp. *Harmonie Universelle* 3:45-46 ("Livre premier des instrumens," proposition 19.) Beeckman also suggested an improved method of pitch standardization, namely, to use a bronze wire of given length, weight, and tension instead of a pipe or string: *JIB* 3:132.

¹⁷ Admittedly there is a fourth property, the phase of the wave, but this does not influence the sensation of sound; see Juan G. Roederer, *Introduction to the Physics and Psychophysics of Music* (New York: Springer, 1975²), p. 38.

¹⁸ *JIB* 1:249; see Cohen, *Quantifying Music*, p. 30 (for Kepler), and p. 101 (for Mersenne).

no secrets for them either, apart from a terminological one: in terms of the pulse theory, the property we now call amplitude was called the amount of air struck. But the third property, tone quality, did cause difficulties, for with what property of a succession of pulses could it possibly correspond? Mersenne's inspired guess¹⁹ that the mix of partial tones determined tone quality was entirely correct, but it was not suitable for being formulated in terms of a property of pulses. So Mersenne's and Beeckman's knowledge of the physics of tone production can be rendered as follows (see figure 3:)

Sensation		Pulse theory
pitch	-	frequency
loudness	-	quantity of air struck
tone quality	-	?

Fig. 3

For Mersenne here, perforce, the matter ended. But not for Beeckman. For in his view the vibrating string divides the air into little globules. This theory entails a dramatic increase in relevant variables: whereas in the pulse theory three properties of musical notes are confronted with only two distinguishable properties of pulses, the corpuscular theory of sound offers a veritable *embarras du choix*: within the limits set by the mechanical philosophy the globules can be said to differ in size, in shape, in density, in quantity, in speed, and so on. And, indeed, Beeckman was embarrassed by the choice available: at different places in the diary we find different attributions. Undoubtedly he would have noticed the resulting inconsistency if he had assembled his disparate notes for publication, but this is precisely what he never did.

On New Year's day 1625, in a discussion of the human voice, Beeckman distinguished between three properties of musical sound: pitch, loudness, and 'fullness' (as opposed to 'thinness').²⁰ The latter property he attributed to the size of the globules, loudness to the density of their aggregate (the closer the globules were together, the louder the voice,) and pitch to speed: the faster a globule was emitted, the higher the resulting pitch. If it is permitted to interpret the 'fullness' of a voice as a measure of its tone quality, we get (see figure 4:)

¹⁹ Cohen, *Quantifying Music*, p. 103.

²⁰ *JIB* 2:314-315. Here *altus* means loud, as opposed to *submissus* = low; *acutus* = high-pitched as against *gravis* = low-pitched; *plenus* = full, and *exilis* = thin.

Sensation		Particle theory
pitch	-	velocity
loudness	-	density of the aggregate (=quantity)
tone quality	-	size

Fig. 4

Combining these attributions with his new, anti-Aristotelian ideas on motion, he was now able to explain why, of all voices, a loud, full, and high-pitched one can cover the greatest distance.

Apparently this was only an *ad hoc* explanation, for on other occasions Beeckman made other attributions. At one time he associated tone quality with the shape of the sound particles;²¹ at another he rather vaguely stated that the differences between the sounds of different musical instruments should be attributed to the various 'dispositions' the particles acquired towards each other.²²

Loudness, however, he always associated with the amount of corpuscles emitted.²³ This helped to explain at the same time why it is that higher sounds tend to be louder as well, since pitch, in this view, is also related to the amount of globules produced. This comes to pass as follows. The more often a string vibrates, that is, the greater its vibrating speed, the smaller are the globules that are cut off the surrounding air. The sizes of the particles are inversely proportional to pitch: a note of given frequency is produced by globules twice as large as those of a note of double frequency. And this implies that twice as much air is cut off; thus loudness increases at the same time. The whole procedure is compared to shaking a salt-cellar: the faster and by the more frequent movements of the hand this is done, the finer the resulting grains of salt.²⁴ (Perhaps these are the very grains of salt with which we should take the whole corpuscular theory of sound.) So now we get the following picture (see figure 5:)

Sensation		Alternative particle theory
pitch	-	size→quantity
loudness	-	quantity
(tone quality)	-	mutual disposition)

Fig. 5

²¹ *JIB* 1:177.

²² *JIB* 1:92-93.

²³ *JIB* 2:196-197.

²⁴ *JIB* 1:252-253.

In particular the association of pitch with the size of the sound globules turned out to be helpful. It could easily be quantified, and thus be put to use in order to explain certain other phenomena. The first of these was the *overtones*. Beeckman did not discover the overtones himself, but when Mersenne, in the beginning of the thirties, communicated his discovery to him, Beeckman could immediately provide the explanation. According to Beeckman,

a string, by its tremor dispersing the air, breaks it into nearly equal globules; however, as all parts of the string tremble equally frequently indeed, but not equally fast, and as some particles of air are perhaps more fragile than others, and as the thickness of the string is not everywhere exactly the same, it happens that a certain amount of those globules is broken into two, three, four, etc. parts. Those that are broken in two represent to the ear the *octave*, because in the same time it is affected by a doubled sting;²⁵

and so on with the other partials up to and including the sixth one.

This explanation refers directly to the second application Beeckman made of his corpuscular theory of pitch: it helped to explain *consonance*.

The Nature of Consonance

In accordance with the dual nature of Beeckman's analysis of sound in terms of pulses and in terms of the sound particles produced by them, he gives a double explanation of consonance as well. Since the sound globules are smaller in proportion to frequency, the ratios of the consonances are the same as those of the sizes of the globules; for instance, the sizes of the globules that make up the octave are in the ratio 2:1. This explanation can only possibly be a complete one if it is extended to an explanation of how the differently sized globules affect the sense of hearing.²⁶ Beeckman's alternative explanation of consonance follows from his analysis of the sounding string, combined, again, with his corpuscular conception of sound.

According to current acoustical theory, sound consists of a succession of waves. It is the *succession* that constitutes the sensation of sound; one

²⁵ *JIB* 4:187, 214-215: "Chorda tremore sua aerem dispergens, eum in aequales ferè globulos frangit; attamen cùm omnes partes chordae aequè frequenter, sed non aequè celeriter tremant, et aliae aeris particulae alijs fortasse fragiliores sint, nec chordae crassities ubique sit exactè aequalis, fit ut eorum globulorum quidam in duas, tres, quatuor etc. partes frangantur. Quae in duas frangantur, octavam auribus repraesentant, quia eodem tempore duplici puncturâ afficiuntur..."

²⁶ For a discussion of Beeckman's ideas on this subject, see Cohen, *Quantifying Music*, p. 139.

cannot point to one particular stage of the wave and declare it responsible for the creation of sound. But the 17th century pulse theory was conceived in such a way that every single pulse was thought to correspond to one particular bit of sound. Mersenne thus devoted an entire proposition of his *Harmonie Universelle* to an inquiry into what portion of one to and fro motion of a vibrating string was actually responsible for bringing forth the sound bit.²⁷ Obviously such an analysis was even more imperative for Beeckman, since he believed that sound consists of particles that are cut off the air by a moving string. For this implies that *during those stages of the pulse when the string does not move, no globules are created, and therefore no sound is produced*. And these stages occur precisely at the extreme points of the vibrating motion: in between ‘to’ and ‘fro’ there is a minute pause, and that is where silence prevails.

All this may be clarified by an analysis of the octave. Let be given two strings AC and DF, B and E being their respective mid-points (see figure 6:)

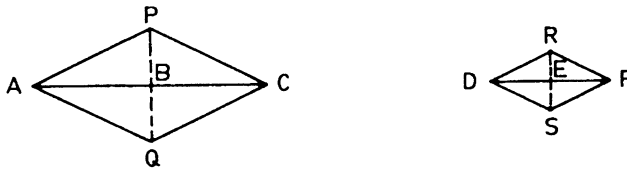


Fig. 6

DEF is half ABC, since we are considering the octave. P and Q are the points of maximum displacement of the longer string, R and S of the shorter. Let us suppose for the moment the vibrating to take place in the void, so that after release the displacement continues to be maximal.

Now Beeckman's essential point is that in positions ABC and DEF the speeds of the vibrating strings are maximal, while in positions APC, AQC, DRF, and DSF the string is momentarily at rest (the so-called '*media quies*', or 'intermediate rest' Beeckman posited in between the successive contrary motions of any body whatever.)²⁸ And since we have already seen that the distance RS is covered twice as frequently as PQ, the sound-silence pattern of the shorter string repeats itself twice as often as that of the longer one. *The resulting regularity is what pleasantly affects the ear*: this is Beeckman's main explanation of consonance.²⁹

²⁷ *Harmonie Universelle* 1:171-172 ("Livre troisieme des mouvemens & du son des cordes," proposition 7; see also proposition 3.)

²⁸ *JIB* 2:23.

²⁹ *JIB* 1:53-55.

Formally this explanation is quite similar to the coincidence theory formulated by Benedetti, Galileo, and Mersenne. But materially it is different, since not the more or less frequent coincidence of certain pulses, but rather the greater or lesser regularity of a definite sound-silence pattern is invoked to explain consonance. The difference is due to Beeckman's corpuscular conception of sound, and it seems fitting to mark it by giving his explanation a distinct name, for instance the *regularity theory of consonance*.

Clearly to a large extent the implications of the regularity theory are the same as those of the coincidence theory. In Beeckman's view the coincidence of sound with sound alternated by the coincidence of silence with silence is consonance, and thus the only pure consonance is the unison. All other intervals consist of mixtures of, on the one hand, such 'unisons', with 'dissonances', i.e. sounds concurring with silences, the latter case presenting itself when the one string is still in motion while the other is momentarily at rest. The more often such 'dissonances' are interrupted by such 'unisons', the more consonant the interval in question is.³⁰ Thus we arrive at exactly the same ordering of degrees of consonance as can be derived from the coincidence theory, and thus we run again into all the difficulties this scale has already appeared to entail. How did Beeckman meet them?

The Regularity Theory Put to the Test

Beeckman was quite aware that, in reality, the vibrations of a string are not made in the void, but in the air, and that this means that the displacement of the string is progressively dampened. Since pitch appears not to change thereby, Beeckman could once more conclude that pitch is related to frequency, not to amplitude: the acoustical counterpart of diminishing amplitude is diminishing loudness. However, and this is a crucial point of Beeckman's theory of consonance, not only loudness is reduced by dampening, *but there also occur changes in the sound-silence pattern* produced by the vibrating string. What happens is the following:

...the impulse weakens, so that it does not always strike the ear with equal violence, and as a result there is not so much difference as before between the stroke itself and silence, that is, rest; and the strokes do not last so long, and their extremities are shaved off and do not reach the sense of hearing, so that greater silences are produced. As therefore the difference between the sound itself and silence is small, the ear does not distinguish sound from rest, in the same way as the eye takes as continuous things that are far away, perforated and discrete, because of the small apparent difference between the images of a hole and the thing itself

³⁰ *JIB* 1:160-161.

and its holes: for only little light reaches the eye from things far away. Thus the sound seems continuous, and a perpetual murmuring.³¹

In short: “the musical note languishes perpetually, and becomes more continuous.”³² And just as in the case of vision the middle hole of the object far away is still perceived best,

just so a continuous sound, too, is by far the easiest divided into two, because, as in seeing, there is only one middle that is equally affected everywhere.³³

In Beeckman’s view it is broadly true that the human mind has a predilection for dichotomies, examples of which he signals repeatedly throughout his diary. For instance, it helps to explain why the perception of the octave is so similar to that of the unison: a pause of the upper string coincides exactly with the middle of the stroke of the lower,

so that the sense of hearing cuts the lower into two equal parts through the middle point of silence, which bisection has been said to be the easiest and therefore the most pleasant.³⁴

On the basis of these two principles: the increasing continuity of every musical note and the human preference for bisection, Beeckman now constructs a revised scale of degrees of consonance.

The Degree of Consonance of the Fourth

As the difference between sound and silence is gradually reduced, the mind in the end tends to add two strokes together, and to take them for one. For example, the fifth 3:2 tends to get perceived as 3:1, which implies

³¹ *JIB* 1:249: “At etiam ex tarditate hac incitatio languescit, ita ut non semper aequali violentiâ aures feriat, unde fit ne tantum discrimen sit quàm antè inter ictum ipsum et silentium, id est quietem; atque ictûs non sunt tam diuturni, extremitatibusque eorum derasis neque ad auditum pervenientibus; unde fiunt silentia majora. Cùm igitur parva est differentia inter sonum ipsum et silentium, auris non distinguit sonum à quiete, eo modo quo oculus longinqua, perforata et discreta habet pro continuis, propter parvum discrimen quod apparet inter imagines foraminis remque ipsam ipsaque foramina: parum enim lucis e longinquis rebus oculis ingreditur. Sic sonus videtur continuus perpetuumque murmur.”

³² *JIB* 1:250: “Cùm haec ita se habeant voxque perpetuò languescat magisque continua fiat...”

³³ *JIB* 1:250: “Sic igitur etiam sonus continuus facillimè omnium bisecatur, quia, ut in visibili, una tantùm est medietas, undique aequaliter affecta.”

³⁴ *JIB* 1:251: “Diapason per se placet maximè, quia medietas silentij chordae acutioris exactè coincidit cum medietate vocis gravioris, ita ut auditus graviolem secet in duo aequalia per medietatem silentij, quae bisectio dicta est facillima ideòque gratissima.”

that “a lower octave, that is explained by the smaller number of strokes, appears to be represented and to be heard a little.”³⁵ But the upper string, which produces three strokes in the time the lower one needs for two, cannot be bisected in this way. Similarly the major third degenerates into 5:2, and is thus ‘represented’ to the mind as the major tenth. But in the case of the fourth the situation is different. Here the *lower* string is represented by an odd number, and therefore it cannot dissolve into the lower octave. But neither can the even-numbered upper string:

The upper string cannot represent the lower, nor the lower the upper, because the ear perpetually conceives as higher that which is higher, and that which is lower can never appear to the ear as higher than the other. Therefore, when it gets languid, the lower string is divided, but the strokes of the upper string are multiplied, that is, in the case of the lower string two strokes are conceived as one; at the upper string each stroke is halved and is taken for two strokes.³⁶

And now Beeckman has achieved his purpose:

From this it is clear that the fourth 4:3 degenerates into the eleventh 8:3, which is worse than the major tenth 5:2, and is therefore employed less often in counterpoint.³⁷

What to make of this strange theory, which is perhaps the least plausible of all of Beeckman’s ideas on music? What, in particular, does he mean by these higher and lower octaves being ‘represented and heard a little’? Beeckman never refers to any empirical counterpart of this ‘representation’. In the case of the higher octave to the upper string ‘being heard a little’, it is tempting to think of the first upper partial. But when, more than a decade after Beeckman framed his theory, Mersenne mentioned to him his discovery of five upper partial tones, Beeckman was surprised, and the explanation he then gave of the phenomenon had nothing at all to do with his theory of the languishing of the consonances.

The case of the lower octave is even more baffling. If Beeckman refers here to a representation that is not purely mental, but rather is given by experience, then he has unwittingly discovered the differential tones, the dis-

³⁵ *JIB* 1:250: “patet octavam graviorem, quae paucioribus ictibus explicatur, repraesentari et subaudiri.”

³⁶ *JIB* 1:324: “Superior verò chorda non potest repraesentare inferiorem, neque inferior superiorem, quia id, quod superius est, auris perpetuò pro superiore ducit atque id, quod est inferius, auribus nunquam alteri superius potest videri. Inferior igitur chorda languescendo dividitur; superioris verò ictus multiplicantur, id est in inferiore chordâ duo ictus habentur pro uno; in superiore unusquisque ictus mediatur atque habetur pro duobus ictibus.”

³⁷ *JIB* 1:324: “Hinc patet quartam 4.3. degenerare in undecimam 8.3., pejorem decimâ majore 5.2., ideòque in contrapuncto rariùs adhibetur.”

covery of which is commonly ascribed to Tartini (1714).³⁸ These are tones defined by the difference of the frequencies of the notes that constitute the interval played, for example, the difference tone of a fifth given by two notes of 300 and 200 Hz, respectively, has itself a frequency of $300-200=100$ Hz, in other words, it sounds the lower octave to the bottom note. In the case of the major third the difference tone is two octaves below the bottom note ($500-400=100$, and $100:400=1:4$), but it is quite possible, on hearing it, to misjudge it by one octave, as Tartini appears to have done himself. This is so, because differential tones are much weaker than the notes that produce them; in fact they have no objective existence at all, but are artifacts created by and inside our sense of hearing.³⁹

I must confess that I am somewhat at a loss to solve the dilemma. Of course it would be nice to be able to shift backwards the discovery of the differential tone (a phenomenon crucial to later theories of consonance)⁴⁰ by nearly a century. But I fear that too many arguments can be adduced against this interpretation. To begin with, there is this complete lack of reference to actual experience. Add to this that, as we have just seen, in referring to the upper octave generated by the fourth Beeckman can hardly have meant its first upper partial. And finally, the fact is that the fourth *also* produces a difference tone, which sounds a twelfth beneath the bottom note. Altogether I reluctantly prefer the interpretation that we should conceive of those ‘mentally represented octaves’ as nothing but hypothetical constructs introduced by Beeckman in an *ad hoc* manner, just in order to give the major third preferential treatment over the fourth in the scale of degrees of consonance.⁴¹

The greater degree of consonance of both the fifth and the major third is also illustrated through a comparison of the quality of certain chords that contain them: according to Beeckman both C—G—c and C—E—c are better than C—F—c. The first case, C—G—c vs. C—F—c, is simply the harmonic vs. the arithmetical division of the octave, and the reason for the

³⁸ Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, and Leiden: E.J. Brill, 1978), pp. 136-138.

³⁹ Roederer, *Introduction*, pp. 33-37.

⁴⁰ Starting with Hermann Helmholtz, *Die Lehre von den Tonempfindungen als physiologische Grundlage für die Theorie der Musik* (Braunschweig: Vieweg, 1877⁴), in particular chapters 7, 11 and 12; cf. A. Wood, *The Physics of Music* (London: Chapman & Hall, 1975⁷), pp. 165-170 (ed. revised by J. M. Bowers).

⁴¹ Cp. *JIB* 1:338, where Beeckman talks of a “harmony conceived by the soul,” which is caused by the fact that “any given note supplies the sensation [sensum] of the octave below, and many people naturally dividing this octave harmonically” thus make heard the fourth below the written note, whether or not they actually sing it, or “impress it on the soul... by a tacit effort of the mind [tacito mentis nisu].” A reference to more recent theories of consonance that are based on non-existing notes in Geza Révész, *Einführung in die Musikpsychologie* (Bern: Francke, 1946), pp. 95-98.

better quality of the former follows directly from Beeckman's original analysis of consonance:

Why is the so-called harmonic consonance better than the arithmetical? That is, why is it that the harmony becomes more pleasant when someone sings the fifth against the bass and the fourth against the soprano, than when someone would sing the fourth against the bass and the fifth against the soprano?

I answer: because the fourth is less perfect than the fifth, and the lower the fourth is [placed], the more this can be perceived by our ear. For slowly move bottom notes, and therefore the intermediate sounds move on longer before the sounds coincide and a unison is produced; but the upper note, because it emits its sounds quickly, becomes at once a unison with the lower one of that fourth. Thus the discord of the fourth, or rather the difference of its sound from unison, is hardly perceptible; but the more perfect concordance of the fifth is more pleasant to our ear, and by virtue of its own nature more rapidly a unison with the bass is made, because its proportion is as 3:2.⁴²

Next, in order to compare C—E—c and C—F—c (that is, chords given by 4 5 8 and 3 4 6,) this type of analysis is combined with the idea of the languishing of intervals. In both cases the upper note is bisected, but in C—F—c the bisection cannot be continued at the bottom note, whereas in C—E—c the bottom note (4 being an even number) can be bisected as well, thus producing the octave below, as required.⁴³

The Degree of Consonance of the Thirds and the Sixths

The bisection through languishing posited by Beeckman has consequences for the fifth and the major third only. The other consonances, whose bottom notes are given by odd numbers, are not affected by it. Thus the adjusted regularity theory of consonance would result in the scale of degrees of consonance given in figure 7:⁴⁴

⁴² *JIB* 1:58: "Cur consonantia harmonica, quam vocant, praestat arithmeticae? id est: cur jucundior fit harmonia, si quis quintam canat contra bassum et quartam contra superium, quàm si quis quartam caneret contra bassum et quintam contra superium? Respondeo: Quia quarta est imperfectior quintâ, quòque quarta est inferior, eò magis auribus nostris est perceptibilis. Tardè enim voces inferiores moventur, proptereaue soni intermedij diutiùs moventur antequam soni coincident et unisonus fiat; superior verò vox, quia sonos suos velociter mittit, statim unisona fit cum illâ quae ipsâ quartâ inferior est. Ergo discordia quartae, aut potiùs diversitas sonoris ejus ab unisono, vix est perceptibilis; quintae verò perfectior concordantia auribus nostris gratior est citiùsque natura sua cum basso unisona fit, quia ejus proportio est ut 3 ad 2."

⁴³ *JIB* 1:246-247.

⁴⁴ This scale is not stated explicitly. However, it follows immediately from the combination of the pertinent statements in *JIB* 4:158, and *JIB* 3:164-165, made in 1629 and

unison			1:1
octave			2:1
fifth	3:2	→	3:1
major third	5:4	→	5:2
fourth	4:3	→	8:3
major sixth	5:3	→	10:3
minor third	6:5	→	12:5
minor sixth	8:5	→	16:5

Fig. 7

Beeckman even goes so far as to quantify pairwise degrees of ‘goodness.’ For example, at the 36th stroke the strokes of the fifth have united 12 times, and those of the fourth 9 times; thus at the 36th stroke the fifth surpasses the fourth by $12-9=3$ degrees of goodness. But the major third does not surpass the major sixth by 3 degrees until the 40th stroke has been made. And so on.⁴⁵

Sympathetic resonance and the Distinction Between Consonance and Dissonance

Having thus settled the problems deriving from the need to make the scale of degrees of consonance conform to experience, the task remains to find a distinguishing criterion between consonance and dissonance. Beeckman takes it from his analysis of *sympathetic resonance*.

As we have seen,⁴⁶ Kepler in 1619 extended Fracastoro’s explanation of resonance at the unison to the octave and the fifth. At least one year earlier Beeckman noted roughly the same explanation.⁴⁷ When, in 1628, he read *Harmonice mundi*, the coincidence struck him at once, and he noted the similarity between his own account and that of the ‘acute philosopher’ he admired so much.⁴⁸

However, there were two important differences. The first had to do with Kepler’s account of the way the vibrations of the sounding string are transmitted to the second string tuned at the unison, the octave, or the fifth. Beeckman quoted Kepler’s statement:

1630, respectively. (*JIB* 1:191 gives a slightly different order, but it is made in passing; it is dated 1618, and may safely be assumed to be just a mistake.)

⁴⁵ *JIB* 3:164-165.

⁴⁶ Cohen, *Quantifying Music*, p. 30.

⁴⁷ *JIB* 1:165-166 (dated 1616-18).

⁴⁸ *JIB* 3:66-67.

then the sound of one [string], that is, the immaterial species of the body of the string, when it is made to vibrate and has left its string, strikes the other string.⁴⁹

And he immediately added:

Never would I have called sound an immaterial species. For how can something immaterial move something material?⁵⁰

As could be expected from Beeckman, his own explanation of resonance was corpuscular. With its help he was able to overcome a second objection that could be raised against Kepler's account of resonance: in the case of the non-vibrating string tuned at the octave it was not at all clear how the odd-numbered pulses, that tended, through coincidence, to strengthen the sympathetic motion, were able to overcome the dampening effect of the equally numerous even-numbered pulses. And of course this objection applied *a fortiori* to resonance at the fifth.⁵¹

Before discussing Beeckman's thinking on resonance, it might be helpful to make it clear that, from the point of view of current acoustical theory, his attempts as well as those of his contemporaries were doomed to failure at the outset. In fact resonance at the octave, the twelfth, and so on, is caused by the corresponding upper partial tones of the vibrating string. For instance, a string tuned at the twelfth g of a string sounding C is made to resound if and only if this C contains the second upper partial g. Thus, in the case of higher-tuned strings, there is no other resonance than at the unison, either directly, through the fundamental, or indirectly, through an upper partial (see figure 8):

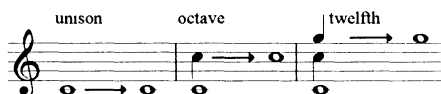


Fig. 8

This implies that the relative strength of resonance depends on the overtone mix of the note given by the vibrating string.

⁴⁹ Johannes Kepler, *Harmonice Mundi*, ed. Max Caspar, in Kepler, *Gesammelte Werke*, 20 vols. (Munich: C.H. Beck, 1938-1988), 6:106: "tunc sonus unius [chordae], id est species immateriata corporis chordae, constitutae in vibratione, delapsa à sua chorda, ferit chordam alteram..."

⁵⁰ *JIB* 3:67: "Nunquam enim ego sonum vocaverim speciem immateriatam. Quî enim immateriatum movere possit materiaturum?"

⁵¹ Mersenne apparently raised this objection in a 1630 letter to Beeckman: *JIB* 4:180; but Beeckman had been aware of it from the beginning: *JIB* 1:165-166 (1618).

Beeckman first discussed resonance at some time around 1617, when he was only aware of resonance at the unison and at the octave. The mechanism of resonance is as follows:

I say that the touched string partly pushes away from itself the untouched string in the process of dispersing particles of air, partly, through [the vibration of] its own body, moves the air nearest to itself, which motion moves the following [layer of air] up to the untouched string; and when the touched string returns, it [the untouched string, that is] is moved only by the motion that commonly, though wrongly, is called ‘eschewing the void.’⁵²

And this mechanism accounts not only for resonance at the unison, but also at the octave. The point Beeckman is making here may be clarified by figure 9:

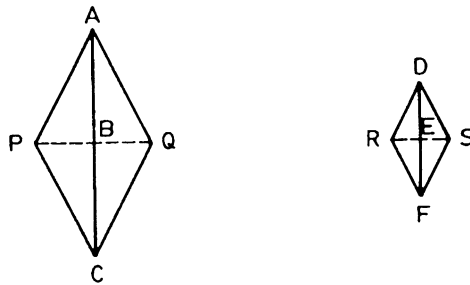


Fig. 9

The rarefaction of the air caused by the second stroke made by string AC at ABC, on its return from position AQC to APC, gives some extra impulse to the motion of DF, so that the dampening effect of this second stroke, though strong, is not complete. Beeckman also notes that during the last stage of the second pulse the corresponding movements from ABC to APC and from DSF to DRF are in the same direction. The net result is that the even-numbered pulses exert less force than the odd-numbered pulses, so that the resonance is continually strengthened, *q.e.d.*

In 1631 Beeckman used this result for proving that (as he believed to be the case) resonance at the major tenth is the strongest of all.⁵³ The proof is based on the fact that, as we have seen, in Beeckman’s corpuscular view of

⁵² *JIB* 4:206-207: “dico nervum tactum partim, particulas aeris disijciendo, à se nervum intactum repellere, partim aerem sibi proximum movere, suo corpore, qui motus movet sequentes usque ad nervum intactum; at quando nervus tactus recurrit, solo motu (quem vulgo, sed malè, *fugam vacui* vocant), moveri.” This passage from a letter to Mersenne renders in a more succinct way Beeckman’s diary notes from c. 1617, see *JIB* 1:165-166. See for Beeckman’s ideas on the ‘*fuga vacui*’ Cornelis De Waard, *L’expérience barométrique. Ses antécédents et ses explication* (Thouars: Deux-Sèvres, 1936), chapters 6 and 13.

⁵³ *JIB* 4:206; *JIB* 3:222.

sound every single vibration creates a succession of sounds and silences, silence being the result of rests at the extremities, and sounds being produced by the globules cut off the air by the string while in motion. The strength of resonance depends on the coincidence of sounds with sounds and of silences with silences. Thus the coincidence of strong sound from the vibrating string with a rest at the untouched upper string has a dampening effect. And dampening is maximal when maximum motion in the one string coincides with maximum *contrary* motion in the other. Moreover, the transition from silence to sound and *vice versa* is a gradual one, since the number of globules produced increases with the speed of the vibrating string reaching and passing through its equilibrium position ABC. Thus the resulting sound-silence patterns at the various intervals can be compared not only in words—as Beeckman did—, but also by means of curves—as Beeckman, unfortunately, only suggested:

Let whoever would like to do so examine more accurately the exact strength by a graphic delineation through compass and ruler.⁵⁴

For carrying out this suggestion would unfailingly have led Beeckman to ascribing a wave pattern to the vibrational motion of sounding strings, as is shown in figure 10 for the octave, the twelfth, and the major seventh.

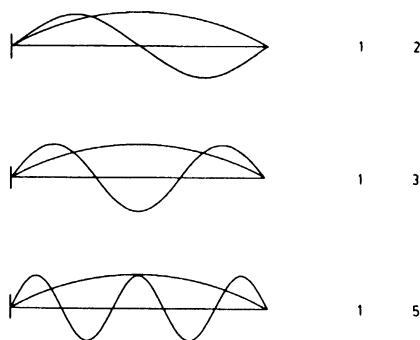


Fig. 10

⁵⁴ *JIB* 1:249: "Exactam vim, qui volet, graphicâ delineatione per circinum et regulam, accuratiùs examinet." This is the final line of the first diary note in which sound-silence patterns are applied to comparing the strength of resonance at different intervals. The note was written in December 1618, occasioned by Descartes' observation that resonance occurs at the fifth, but not at the fourth (Beeckman learnt the method of graphic representation also from Descartes, whom he had just met for the first time.) I have not been able to find a completely consistent interpretation of Beeckman's attempted proof that, in contrast to the fourth, the fifth, and also the major third (!), do give rise to resonance.

Thus even the corpuscular theory of sound could eventually have given occasion to analyzing sound in terms of a succession of waves. But Beeckman, in refraining, for whatever reason, from actually drawing the graphs, just missed the inevitable consequences. (Of course, in the end he would have had to give up his corpuscular theory of sound, which thus would have been overthrown by its own implications.)

However this may be, the required proof has now become easy. At the octave, as we have seen, the second part of the stroke of the lower string only just succeeds in overcoming the dampening effect of the contrary motion of the vibration of the upper string. Similarly, in the case of 1:3, the fastest, and therefore strongest, part of the motion of the lower string coincides with the maximum intensity of the *contrary* motion of the upper string. But in the case of 1:5,

when the upper string moves five times in the time the lower string moves once, the first, middle, and last strokes concur with the lower string; admittedly the second and fourth [stroke] run counter to it, but the second and fourth do not appear to overcome the first and the fifth as much as the third alone the second and the fourth; thus for the whole stroke the concurrence is stronger.⁵⁵

Thus 1:5 gives the strongest resonance, and the application to this result of Beeckman's languishing theory gives at once the required proof of the superiority of resonance at the major tenth 2:5.

But Beeckman is now able to draw one more conclusion, for the benefit of which we had to include in our discussion of consonance this long digression on resonance. *For it follows from Beeckman's corpuscular theory of sound that resonance and consonance are closely related phenomena:* both the strength of the former and the quality of the latter are determined by the sound-silence patterns that characterize the intervals in question. So now Beeckman is finally in a position to explain why consonance stops at the minor sixth, in other words, to give a physical criterion for the distinction between the consonances and the dissonances. The starting points of the argument are the superior strength of 1: 5 just proved, and the fact that the unison, with its perfectly regular alternation of sound and silence, is the quintessential consonance:

From this a more accurate reason can be sought why the number of consonances is limited to the *senario*, for 4:5, 5:6, 5:8, 3:5, that appear to be farther re-

⁵⁵ *JIB* 4:206: "Verum in 1.5/ [i.e., 1:5], cum superior chorda quinquies movetur eo tempore quo gravior semel movetur, ictus primus medius et ultimus cum graviore chorda conveniunt; secundus verò et quartus illi occurrunt, nec tantum secundus et quartus videntur superare primum et quintum quantum tertius solus secundum et quartum; toto igitur ictu convenientia est fortior."

moved from unison, and take their origin from 1:5, the strongest of all consonances, as... we have proved.⁵⁶

Thus only those intervals are consonances that are directly derived either from unison, 1:1, or from the twentieth, 1:5.

By the same token an interval such as 6:7 is a dissonance. In the first place it is derived from 1:3, which is worse than 1:5, and from 1:7, which is so even more (see figure 11.) For in the case of 1:7 again the maximum sound emitted by the lower string coincides with the mid-point of a contrary motion of the upper string, which thus leads to considerable dampening:

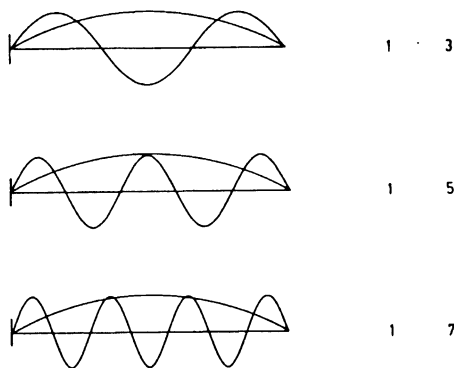


Fig. 11

Next, 1:7 is four degrees worse than 1:3. Thirdly, the derivation of 6:7 from 1:7 is weak and very long, for 6:7 is as much worse than 3:7, as 1:2 is worse than unison, and 3:7 [is as much worse] than 1:7 as 1:3 [is worse] than 1:1.⁵⁷

In the same way 7:8 is a dissonance, since its derivation from 1:7 takes no less than four bisections, and 1:7 is much less fit than 1:5 to generate consonances anyway. Similar analyses serve to exclude all other intervals, like 10:11, 15:16, and so on:

⁵⁶ *JIB* 3:222: "Hinc accuratio ratio peti potest cur consonantiarum numerus in senario finiatur, nam 4: 5/5: 6/5: 8/3: 5/ [i.e., 4:5, 5:6, 5:8, 3:5] quae longiùs ab unisono videntur distare, omnes originem sumunt ab 1: 5/ [i.e., 1:5], consonantiarum omnium fortissimâ, uti in dictâ epistolâ probavimus."

⁵⁷ *JIB* 3:222: "Deinde 1:7 quatuor gradibus deterior est quàm 1:3. Tertiò deductio 6:7 ad 1:7 est longissima et infirma, nam 6:7 tantò deterior est quàm 3:7, quantò 1:2 deterior est quàm unisonus; et 3:7 quàm 1:7 quantò 1:3 quàm 1:1."

Between all these and the four so-called imperfect consonances there is no proportion of goodness (as is to be seen from these [considerations]) but they are almost infinitely worse.⁵⁸

Untenable as this theory obviously is (for we have already said that the strength of resonance depends on the mix of partial tones of which a musical note consists,) it raises an intriguing problem. For what precisely could be the justification for taking as similar the strength of resonance and the quality of consonance? The argument on dampening through contrary motion is correct as far as it goes, but what relevance could it possibly have for consonance? In Beeckman's view consonance is determined by the regularity of a definite sound-silence pattern. But how could the ear distinguish between sounds originating from contrary motions? Are not all sound globules alike independent of where they come from? *Contrary motion could affect the ear only if it functioned itself as a resonating string.* Whether or not this was actually Beeckman's view we shall see presently.

The Ear and the Soul

We have already seen that in Beeckman's view the sound that reaches the ear 'is the very same air that was in the mouth of the speaker.' The globules emitted by a string derive their velocity from the force with which the vibrating string hits them. In the case of the pipe their motion is partly due to the movement of the incoming wind that is cut into globules, partly it derives from the spring of the air inside the pipe that is compressed by the globules and, in springing back, chases them out of the pipe.⁵⁹ Every single globule flies on its own;⁶⁰ every single globule is homogeneous, and represents in its particular shape and size the properties of the resulting sound.⁶¹ However, during their flight through the air the globules do not yet constitute sound: they are still nothing but the 'substance of sound.'⁶² If a globule does not reach an ear it finally comes to rest, according to the laws of projectile motion, and is then reintegrated in the surrounding air.⁶³ Only in affecting the brain through the mediation of the eardrum are the

⁵⁸ JIB 3:222: "Inter haec omnia et quatuor imperfectas dictas consonantias nulla (ut ex his videre est) proportio est bonitatis, sed infinitè ferè deteriora haec sunt."

⁵⁹ Cf. Cohen, *Quantifying Music*, pp. 147-148.

⁶⁰ JIB 3:53.

⁶¹ JIB 3:56, 59.

⁶² JIB 1:93; the term 'the substance of sound' in JIB 3:61: "de substantie des geluyds..."

⁶³ JIB 2:34-35.

globules turned into actual sound. In which way can we imagine this process to develop?

Again nothing but a corpuscular explanation is able to satisfy Beeckman. He does emphatically *not* believe that the human mind itself is amenable to a reduction in terms of matter and motion. However, as far as body-mind *interaction* is concerned he deems it not *a priori* hopeless to search for underlying material processes. He admits, in 1628, that this is a very difficult problem, and the reasons he has found so far do not entirely satisfy him.

But this foundation [should be] posited, that [... ; e.g.] the sounds of the consonances actually cause, through motion, something inside us to change place...⁶⁴

Before plunging into Beeckman's investigations as to the nature of such a motion, we should realize ourselves that accounting for the perception of the consonances involves two distinct tasks. In the first place an account is needed of how the affection of the eardrum by the air (in whatever way we have to imagine the nature of this affection) is transformed into the sensation of sound. Secondly, and more specifically, we have to look for some mechanism by which the *regularity* of the affection, as given by the frequency ratios of the consonant intervals, is turned into *pleasing* sound. As to the latter, Beeckman had two strings to his bow. On the one hand he defined consonance as the regular alternation between coinciding sounds and coinciding silences. On the other, in his view the consonances were characterized by sound globules of sizes inversely proportional to the simple ratios of frequencies of the constituting notes. These notions were the starting points Beeckman had at his disposal; let us see now how far they could take him towards a mechanistic explanation of the pleasure of the consonances.

In the only diary note he devoted exclusively to the sense of hearing (dated 1631,)⁶⁵ he first discussed the outer ear, in particular the membrane at the end of the auditory passage that separates it from the middle ear: the eardrum. It is stung, as it were, by small globules; larger ones violently shock it. This action of the sound globules on the eardrum is like the ruffling of a military drum, supposing that the soldier who operates the drumsticks were able to ruffle it with greatly increased agility. In order to explain the transmission of the stings and shocks, Beeckman extends the comparison to the middle ear. He is acquainted with its anatomy (see for a present-day picture Figure 12:)

⁶⁴ *JIB* 3:69: "posito tamen hoc fundamento quòd... consonantiarum soni, aliquid reverâ in nobis loco moveant..."

⁶⁵ *JIB* 3:187; cf. *JIB* 1:125.

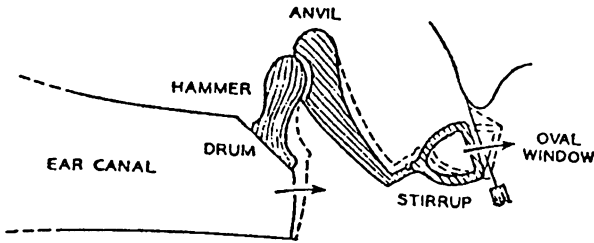


Fig. 12. From J.R. Pierce and E.E. David, Jr., *Man's World of Sound* (Garden City, NY, 1958). Reprinted by permission.

(The membrane now known as the oval window was called by Beeckman the inner membrane.) Now the affection of the eardrum is transmitted through the inner air to the inner membrane in the same way the bottom membrane of the military drum is moved by the motion of the air inside the drum:

...the skin of a drum, when struck by a stick, gives sound because the inner air is squeezed and compressed, and it moves the sides with retrograde motion, and at once springs back to the skin itself.⁶⁶

In this process the role of the three ossicles is only secondary. They just take over the motion of the drumskin and pass it on to the inner membrane, thus doing nothing but reinforcing the stings and shocks the inner membrane receives through the motion of the air inside the middle ear.

Finally, the inner ear. Of its structure Beeckman knows virtually nothing.⁶⁷ In his view the inner membrane is the entrance of the acoustical nerve that connects the ear with the brain. Beeckman accounts for the

⁶⁶ *JIB* 1:313: "Sic corium tympani baculo pulsum, edit sonitum quia aer intrinsecus in se pellitur, cogitur, movetque latera retrogrado motu, ad ipsumque corium statim resilit."

⁶⁷ This omission is rather strange, since the inner ear is mentioned in at least two modern anatomical descriptions of the sense of hearing that were known to Beeckman. Hieronymus Fabricius ab Aquapendente, *De visione, voce, auditu* (Venice: Francesco Bolzetta, 1600), Book 2, repeatedly mentions the cochlea and the labyrinth, for instance on pages 1 and 8. Giulio Cesare Casserio (I. C. Casserius), *De vocis auditusque organis historia anatomica* (Ferrara: Vittorio Baldini, 1601), describes the structure of the inner ear in quite some detail, but Beeckman, who had the book at his disposal for only a few days (*JIB* 3:42), must have overlooked this passage. See for a detailed history of the anatomy and physiology of the sense of hearing Adam Politzer, *Geschichte der Ohrenheilkunde*, 2 vols. (Stuttgart: Enke, 1907), 1.

transmission of the motion through the nerves by means of small particles, called *spirits*. The concept of 'spirits' or 'pneuma' goes back to Galen, who used it to explain sense perception. Galen conceived of the spirits, that are centered in the brain (the seat of the process of perception,) as an immaterial, really 'spiritual' principle rather than as the particles of matter into which they were now turned by Beeckman.⁶⁸ In Beeckman's view the spirits are made of a nerve-like substance. They move either alongside the nerves or through their cavities, just as water runs down a water conduit both through and alongside it. They are connected, as it were, by means of little hooks, and thus form a continuous whole, that is centered in the brain. Spirits moving away from the brain in the direction of, for example, the hands or the feet, cause these members to move, through a mechanism of contraction and relaxation. Incoming spirits, through a similar mechanism, are the material cause of sense perception. An example of this is the sensation of pain:

When our skin is cleved or stung by a nail, we feel pain because the whole structure of our body suffers. For the animal spirits are diffused throughout the whole microcosm; thus, when some part is cleaved, the spirit is cleved as well, and when the spirit is cleved it retreats, just as expanded and dilated air contracts itself.

[As a result of the overall connection,] together with all members the brain, that is the center of all sensation, suffers as well. ...the coarser [the nail] is, and the less the cut [spirit] is contracted, the duller the sensation is.⁶⁹

Now being stung by a nail is exactly similar to being stung by very sharp sound globules, and this is why:

excessively fine sounds seem to me unpleasant, and they sting the spirit of the brain by their very fine-ness, just as a little nail stings the skin; coarser sound [particles] do not hurt solely by virtue of their size, just as light hurts only when it has maximal clarity, and [the light particles] strike the eye too swiftly and sharply.⁷⁰

⁶⁸ Galen's conception of spirits is discussed in Karl E. Rotschuh, *Geschichte der Physiologie* (Berlin: Springer, 1953), pp. 14-17, and Rudolph E. Siegel, *Galen on Sense Perception* (Basel/New York: S. Karger, 1970). See for the properties of the spirits mentioned in the text *JIB* 1:121, 124, 126, 136, 157-158, and 2:28, 123.

⁶⁹ *JIB* 1:124: "Cum cutis nostra scinditur, vel acu pungitur, dolemus quia tota structura corporis nostri patitur. Nam spiritus animales fusi sunt per totum μικρόκοσμον, fissâ igitur aliquâ parte, finditur etiam apiritus, at fisso spirito, retrahitur ad se, non aliter atque aer expansus et dilatatus sese contrahit." *JIB* 1:125: "Patitur igitur cum omnibus membris etiam cerebrum, sensus communes... quòque ille est crassior minusque sectus se contahit, eò sensus est obtusior."

⁷⁰ *JIB* 1:177: "Impraesentiarum, quod ad quantitatem attinet, mihi solae voces supra modum subtiles videntur injucundae, solâque subtilitate pungere spiritum cerebri, non aliter

However, the size of the sound globules is not the only agent of the greater or lesser agreeability of sound:

from the various instruments that emit sound a certain quality originates, that is sometimes delectable, sometimes less so, because the air is cut into parts that do not correspond to the pores of the brain, or of the members, or of the collection of spirits.⁷¹

Let us pause here, and briefly review Beeckman's attempts at defining the material substratum of auditory sense perception. Compared to the few sentences Galileo and Mersenne devoted to the process of hearing, clearly Beeckman turns out to have investigated the matter much more deeply (after all, he had studied medicine; but so had Galileo.) He gave mechanical analogies of the way the affection of the eardrum is transmitted to the oval window and from there to the brain. Of course the state of pre-microscopical anatomy as well as the globule theory of sound seriously impaired the validity of his results. But this is not the main point. From the perspective of his own time a much more serious defect was that, in accounting thus for the process of hearing, *the specific properties of consonance have been lost sight of*. Sound perception *per se* has been mechanically explained, but we still do not know why notes whose frequency ratios are given by the first few integers do sound pleasantly together. The only statements on the pleasure of musical sounds Beeckman made concern the effects of *single* sounds: notes that are too high hurt because their sharp sound globules sting the sense of hearing, and all other unpleasant notes are unpleasant because of 'a lack of correspondance' between their globules and the spirits of the brain. Had Beeckman succeeded in quantifying this lack of correspondance—I admit that I have no idea how he could have done this—, then, and only then, would he have found, a material principle that connects outer regularity with inner pleasure. But in his analysis regularity stops at the inner membrane. As a result the solution to the problem of consonance has only been advanced by one small step, from the end of the outer ear to the end of the middle ear. Compared to the scope of the original enterprise this is not much, but I do not think that the value of the attempt is diminished thereby. Rather, it defines the limits set by the anatomical and physiological knowledge available to the 17th century scientist.

quàm acicula cutem pungit; crassiores voces solâ quantitate non laedere, ut neque lux laedit nisi summâ suâ claritate, nimis celeriter et acutè oculos feriens."

⁷¹ *JIB* 1:177: "sic ex diversis instrumentis, ex quibus vox excutitur, oritur qualitas quaedam aliquando delectabilis, aliquando minus, quia aer in partes secatur quae poris cerebri, vel membrarum, vel collectionis spirituum, non respondent."

However this may be, Beeckman himself hardly appears to have felt that something was lacking from his explanation of consonance. For instance, the diary item that contains the passage quoted above on the disposition of the sound globules of single notes starts by the observation that the pleasure of the consonances has already been accounted for. In Beeckman's view the regularity that characterizes the alternation of sound-silence patterns in the consonances is just one instance of a very general principle: "all sweetness in music consists in identity, and in deviating a little bit from this identity, and in returning to it."⁷² This, in Beeckman's view, is true for all sense perception. Whether in feeling pain, in seeing, or in hearing, our sensations are never evoked instantaneously. Only those affections of the senses can be perceived at all that require a certain duration. Thus sound, in order to be enjoyed, needs to be repeated. But as soon as the thing perceived has been perfectly understood through repetition, it ceases to be pleasant and needs to be varied. Thus the pleasure evoked by the regular sound-silence patterns that characterize the consonances is reducible to a general psychological law of sense perception.⁷³

Obviously the search for a material substratum of this psychological law presupposes, again, a knowledge of the anatomy and physiology of the nerves and the brain that was completely beyond the grasp of science in Beeckman's time. Our account of Descartes' performance in the same field⁷⁴ will demonstrate once more that here was the unsurpassable limit to the attempts of 17th century mechanicians to fill the gap between physical regularity and musical pleasure.

Accounting for Small Deviations from Pure Consonance

In a letter to Mersenne written in 1630, Beeckman casually observed that the strokes of intervals given by ratios that consist of incommensurable terms, such as the consonances in the equal division of the octave, after their common first stroke never again coincide.⁷⁵ We have already seen that this state of affairs had devastating consequences for the coincidence theory of consonance, even though its adherents failed to notice this. However, Beeckman's regularity theory was not thus menaced, because he was in a position to explain why the human ear will hardly perceive very small deviations from pure consonance. This he had already made clear in a diary note written around 1617.

⁷² *JIB* 1:319: "Videbis musicam dulcedinem omnem constare in identitate et in declinando paululum ab hac identitate ac reditu ad eam."

⁷³ *JIB* 1:52-54.

⁷⁴ Cf. Cohen, *Quantifying Music*, pp. 172-175.

⁷⁵ *JIB* 4:180.

In this note he observed that sounding strings are seldom, if ever, found to be in exactly the ratios that define the pure consonances. Suppose this comes about because, in the case of the octave, one string is slightly more than twice as short as the other, then, Beeckman says, the stroke of the lower string will not quite coincide with that of the upper string, but it will strike just a very short instant of time earlier. *This very small difference will not be perceived.* Why this is so Beeckman does not say explicitly, clearly because the reason is, to him, so obvious. For it follows directly from his corpuscular idea of sound, according to which the transition from silence to sound and *vice versa* is gradual. Therefore the ear is not hurt when complete silence coincides with nearly complete silence, and maximum sound with nearly maximum sound. And perhaps after twenty vibrations, Beeckman continues his argument, we will still not hear it. But at some time, after, say, a hundred vibrations, the deviation cannot but become perceivable, for then the difference in time between the strokes and rests of both strings will have become too great, and thus “every hundredth trembling motion of the string will be perceivable.”⁷⁶

At this point Beeckman draws no other conclusion than that

notes of longer duration require more exact strings, and that singing a melody exclusively in whole notes makes it more difficult to make the harmony sweet and pleasant, because, as I said, the hidden defect becomes manifest in time.⁷⁷

Some two years later, in discussing a recipe for tuning the harpsichord, Beeckman notes in passing that the criterion for the justness of the fifths is that they do not ‘wow-wow’, a phenomenon, he says, that is to be observed much more clearly in the organ, both at the fifth and at the octave.⁷⁸

This nice onomatopoeia unmistakably describes Beeckman’s becoming aware of the phenomenon of *beats*. In order to explain them nothing more is now needed than to combine the observation of the phenomenon with the theoretical discussion of slightly deviating consonances referred to above. This happened on the 8th of May 1628, when an organ player of his acquaintance told him that, in order to get the fifths duly tempered, he used to tune them exactly pure, and then

he taps the pipes in such a way that the sounds run counter to each other as if they said wow, wow, wow, the one wow differing from the other in time as much as one pulse in the radial artery from the other, and then all is well. But if he

⁷⁶ *JIB* 1:161: “erit tamen centenus motus trepidus chordae sensilis.”

⁷⁷ *JIB* 1:161: “Hinc sequitur notas majoris morae exactiores chordas requirere difficiliusque perpetuis integris notis melodiam cani, harmoniamque suavam et delectabilem fieri, quia, ut dixi, tempore vitium latens innotescat.”

⁷⁸ *JIB* 1:310.

makes them even more unequal, the wows come still 5 or 6 times closer together; and if he makes them worse again, the sound passes into something like rattling.⁷⁹

Not only is this an early semi-quantitative description of tuning by beats, but also, for the first time, an explanation of the phenomenon is provided. 'Wows,' Beeckman says, come to pass as a result of a slight mistuning: the strokes coincide less and less, until finally the vibrational motion that lags behind is overtaken by the other, and both momentarily coincide again. Every single cycle of lagging and being overtaken makes itself heard as a wow; therefore the closer the notes are together, the more time will be needed for one wow to be heard. For example, a slightly mistuned fifth will wow once every, say, fifty vibrations, which hardly displeases the ear. And if the upper pipe is mistuned more,

it overtakes [the other] every 30th time or so, which begins to take away the agreeability of the fifth. But if it is still worse, it rattles and is really vicious, since now the ratio is no longer as 2 to 3, but as 17 to 18 or 20 to 21 or 10 to 11, etc., which are all dissonances, for instead of the one string [sic] moving three times against the other one twice, the strokes now come together only once every eleven or 12 times, or so.⁸⁰

Let us look into the meaning of this fascinating passage.

Its weakest point is the clumsy quantification: the numbers given are just fancy examples that have nothing to do with relating the number of beats per unit time to the amount of deviation from purity. This failure was the inevitable consequence of Beeckman's professed lack of interest in determining absolute frequency.

But for the rest Beeckman's account of wow-wowling is simply the best that could possibly be given in the context of the state of acoustical theory of his time. This may be illustrated by the following account of beating in a present-day textbook on the physics of music:

Another very important instance of superposition is the phenomenon of *beats*. When two sources of sound of nearly the same frequency are sounded simultane-

⁷⁹ *JIB* 3:51: "so klopt hy de pypen so, dat de geluyden teghen een gaen, gelyck of se seyden wou, wou, wou, het een wou van het ander in tyt soveel verschillende als den eenen pols in arteriâ manûs van den anderen doet, ende dan ist wel. Maer so hy die dan noch wat ongelycker maeckt, so kommen die wouwen wel 5 of 6 mael dichter opeen; ende so hy die noch erger maeckt, so gaet het gelyck oft het ratelde."

⁸⁰ *JIB* 3:51: "so gaet se alle 30 mael of so eens te veel over, twelck nu de behaeghelickheyt van de quinte begint wech te nemen. Maer noch erger synde, so ratelt het ende is heel quaet, dewyle het nu niet meer en gaet gelyck 2 tegen 3, maer gelyck 17 tegen 18 of 20 tegen 21 of 10 tegen 11 etc., twelck al dissonantien syn, want instede dat d'een snare 3 mael behoort te gaen teghen de ander tweemaal, so en passen de slagen maer in elf of 12 reysen ééns op één, of so."

ously, the resulting effect is a periodic alternation of sound and silence which we call beats. It is easy to see how the effect arises. At a given instant the two sets of waves superposed at the observer's ear are in agreement. Compressions arrive together and rarefactions arrive together, and we hear a loud sound. One of the sources, however, is vibrating slightly faster than the other. The waves it sends out begin to arrive earlier than those from the other source. The superposed waves are now in opposition. A compression from one source arrives simultaneously with a rarefaction from the other and vice versa. If the two sounds have equal intensity there will be complete silence. In any case there will be a minimum of sound. Presently the faster source will have gained a whole vibration, the two sets of waves will be in agreement again at the ear, and the sound will give maximum loudness. Clearly the number of beats per second will be the number of complete vibrations which the faster source gains on the slower in one second, and this in turn will be the difference in frequency of the two sources.⁸¹

Despite the absence, in Beeckman's acoustics, of the concept of superposition of waves that arise from successive condensations and rarefactions of the air, it is clear that he captured the essence of the phenomenon of wow-wowling.⁸²

And Beeckman's final line contains one more striking discovery. Admittedly it betrays some inevitable confusion between ratios of intervals and rates of beating, since it follows from his regularity theory that *both* are produced by coinciding sounds and silences. But nevertheless Beeckman appears to be clearly aware that *beating causes dissonance*. Once more we have reason to marvel how a totally wrong starting point (the corpuscular theory of sound,) combined with a remarkable physical 'intuition', could yield, besides obvious failures, some really brilliant discoveries.

Summary of Beeckman's Theory of Consonance

Beeckman's corpuscular conception of sound gave rise to two different analyses of consonance. On the one hand, the consonances were thought to consist of sound globules of sizes inversely proportional to frequency. This quantification of consonance was not used by Beeckman for explaining any of its properties. The size of the sound globules was invoked only in order to explain why very high notes sound unpleasantly.

Much more important was another consequence of the corpuscular theory of sound, namely the alternation between sound and silence that results from the fact that during certain stages of the vibration of a string no sound

⁸¹ Wood, *Physics of Music*, p. 20.

⁸² Another inevitable defect results from the fact that Beeckman does not discuss beating at the unison, but at the fifth, in which case not the fundamentals, but rather the respective second and third partials cause the beating.

globules, or only very few, are produced. This *relative discontinuity of musical sound* is the key to Beeckman's explanation of consonance.

Every note has a characteristic sound-silence pattern of its own, which depends directly on its frequency. Therefore complete identity between two sound-silence patterns is realized only in the case of two notes of equal frequency sounding simultaneously. This identity is what is called 'consonance;' by definition its one pure manifestation is at the unison. Conceptually, dissonance is exactly the reverse: not sound + sound followed by silence + silence, etc., but sound + silence and silence + sound.

Thus consonance and dissonance are opposite principles. All actual musical intervals other than the unison consist of a mixture of the two, and thus they are comparable as to the extent to which they share in this basic element of consonance.

The scale of degrees of consonance that thus would follow from the relative discontinuity of musical sound is revised on the consideration that over time the discontinuity is reduced through dampening. The resulting revision reestablishes the match between physical regularity and aesthetic experience. It also follows from the relative discontinuity of sound that small deviations from purity are imperceptible. This invalidates a major objection to the rival coincidence theory of consonance, and helps to explain wow-wowling.

Next, the explanation of consonance in terms of sound-silence patterns provides a close analogy to sympathetic resonance, which is used for establishing a physical distinguishing criterion between the consonances and the dissonances. On closer inspection we found that this analogy would have been justified only if the ear itself had been conceived as a resonating system. However, in Beeckman's account of the process of hearing no trace of this could be found (small wonder: 'Corti's organ' inside the inner ear, which in 1863 provided Helmholtz with the anatomical basis of his resonance theory of consonance, had by then just been discovered.)⁸³

Instead Beeckman posited a general psychological principle: the relative discontinuity that characterizes consonance finds its exact counterpart in the relative discontinuity that governs sense perception. In this way the chasm between inner and outer regularity is not filled, but rather jumped over in one bold leap.

⁸³ Helmholtz, *Lehre*, pp. 228 ff.

Reassessment

6 Mechanics & Affections

Peter Dear

Marin Mersenne: Mechanics, Music and Harmony

Claude Victor Palisca

Moving the Affections Through Music: Pre-Cartesian Psycho-Physiological Theories

MARIN MERSENNE: MECHANICS, MUSIC AND HARMONY*

Peter Dear

Mersenne accomplished the harmonization of mechanics through the mechanization of music. Not merely for him another of the quadrivial disciplines, music was central to Mersenne's mathematical endeavors because it provided the paradigm of harmony by which the rest could be developed and judged. Mersenne wrote more on music than on any other single subject, starting with the search for its psychological powers derived from the humanist project to restore ancient music.¹ Even after rejecting the humanist path, he continued to pursue the notion of a "musique accentuelle" directed towards similar ends, and in *Harmonie Universelle*, building on material presented in *La verité des sciences*, he discussed combinatorics and its role in determining the most beautiful melody possible, again attempting to bring the effects of music under disciplinary control.² He also, especially in *Harmonie universelle*, considered tuning systems and described specific instruments.

These obviously "musical" interests cannot, however, be separated from those appearing to us as having more to do with the "physics of sound." Although it is easy, and perhaps for certain purposes justified, to see some of Mersenne's investigations as forming a distinct area of study corresponding to the later subdiscipline of "acoustics," there is in fact a firm integration between this and the other parts of his musical work.³ He

* From Peter Dear, *Mersenne and the Learning of the Schools* (Ithaca and London: Cornell University Press, 1988), pp. 139-141, 149-160, and 160-169.

¹ Ibid., chapter 2.

² Ibid., chapter 7. See also, and more generally, Alistair C. Crombie, "Mathematics, Music and Medical Science," in *Actes du XII^e Congrès International d'Histoire des Sciences, Paris 1968* (Paris: Albert Blanchard, 1971), 1B:295-310; idem, "Experimental Science and the Rational Artist in Early Modern Europe," *Daedalus* 115 (1986): 49-74, esp. 63-67; H. Floris Cohen, *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580-1650* (Dordrecht: D. Reidel, 1984), pp. 112-114.

³ Sigalia Dostrovsky, "Early Vibration Theory," *Archive for History of Exact Sciences* 14 (1975): 169-218, does tend to make a separation between the two, concentrating on "acoustics." See also Frederick Vinton Hunt, *Origins in Acoustics* (New Haven and London: Yale University Press, 1978), pp. 82-100; Hunt emphasizes Mersenne's experiments to determine the speed of sound. As a classical mathematical science, music formed a natural focus of study for those interested in such other sciences as mechanics: for a survey, see Armand Machabey, Sr., "Quelques savants-musiciens de l'époque de Mersenne," *Revue d'histoire des sciences* 11 (1958): 193-206.

intended *Harmonie Universelle* as a compendium of all those things the “perfect musician” should know, and to that end he included not only the descriptions of musical instruments, scales, and the art of composition, but also exhaustive treatments of the physical nature of sound, the behaviors of vibrating strings and organ pipes, and the mechanics of movement. Mersenne was certainly not merely taking the opportunity to publish material unrelated to music while putting a properly musical treatise through the press; the full plan of the imperfectly realized *Traité de l’harmonie universelle* had also provided for coverage of those topics.⁴ The various elements were unified by the overall theme of “universal harmony,” which related the evident conjunction of experience and number found in music with the structure of the created world as a whole. Since harmony represented the divine wisdom ordering Creation, a full understanding of it, which Mersenne took to be the goal of the “perfect musician,” necessarily involved discovering how it came to be instantiated in musical sounds.

Time, as Augustine had stressed, played an essential role in our apprehension of the numbers in music. Change and motion, intimately related to time, characterized the physical world, and so musical harmony participated in “universal harmony” through the motion of sound. Mersenne treated sound as a disturbance in a medium, a quasi-mechanization by no means original but which he exploited to establish an identity: sound became movement and, reciprocally, movement became sound.⁵ Thus, “all movements that occur in the air, in water, or elsewhere, can be called sounds, inasmuch as they lack only a sufficiently delicate and subtle ear to hear them; and the same thing can be said of the noise of thunder and of cannon with respect to a deaf person who doesn’t perceive these great noises.”⁶ The first book of *Harmonie Universelle*, on “The nature and properties of sound,” therefore spent its eighty-four pages dealing entirely with sound’s physical—or, more properly, mechanical—characteristics. The order found in music was a mechanical order governing the motion of the producers of musical sounds as well as all other corporeal bodies in the universe.

⁴ Marin Mersenne, *Traité de l’harmonie universelle* (Paris: G. Baudry, 1627), “Sommaire des seize livres de la musique” (following “Preface au lecteur.”)

⁵ For the background to this contention, see Alan E. Shapiro, “Kinematic Optics,” *Archive for History of Exact Sciences* 11(1973): 135-141; and Frederick Bill Hyde, “The Position of Marin Mersenne in the History of Music” (Diss., Yale University, 1954), chapter 6. Aristotle had associated sound with disturbance in the air but did not *identify* the two; the mathematical acoustical treatise by the Jesuit Josephus Blancanus adopts exactly the same position, guided by the Aristotelian disciplinary division between mathematical sciences and physics: Josephus Blancanus, “Echometria,” in *Sphaera mundi* (Bologna: S. Bonomi 1620), pp. 415-443.

⁶ Mersenne, *Harmonie Universelle* (Paris: S. Cramoisy, 1636-37; reprint ed., Paris: CNRS, 1963), “Du son,” p. 2.

Mersenne could not interpret music in mechanical terms at the expense of harmony, however; music, not mechanics, preeminently instantiated the mathematical relationships that he hoped to find throughout Creation. Harmony had to be extended to mechanics even while bringing music within the ambit of mechanical analysis. This meant that, for Mersenne, the criterion for a successful mechanical interpretation of music was that it incorporate the simple numerical Pythagorean ratios to express musical consonances.

The Harmonization of Mechanics

Mersenne therefore sought to retain the musical relevance of the ratios established and justified by Gioseffo Zarlino, because the theory of music that expressed and exemplified universal harmony incorporated them at its heart. The *senario*, however, faced both the embarrassment of Vincenzo Galilei's findings and the threat of being rendered irrelevant by the widespread use of temperament., Benedetti had adumbrated a solution to the difficulty (in a letter, published in 1585 but written two decades earlier,) which gave a physical interpretation to the ratios associated with musical consonance.⁷ It had long been accepted that a note's pitch increased with frequency of vibration and that the shorter a string, *ceteris paribus*, the more rapidly it vibrated. Benedetti asserted that for a given tension, strings vibrate at a frequency inversely proportional to their lengths. Each stroke of the vibration produces a pulse which is transmitted through the air; consonances arise when the pulses from two strings coincide regularly and often. Thus when the lengths of two strings are in a ratio of 2:1, each pulse sent out by the longer string coincides with every second pulse from the shorter. The octave can then be interpreted as a frequency ratio of 1:2 rather than as a transcendental ratio of 2:1 instantiated in string lengths. In the case of the fifth, coincidence of pulses occurs once every second cycle of the longer string and once every third cycle of the shorter, a frequency ratio of 2:3. Benedetti drew up a table assigning to each consonance its own number, corresponding to the product of the relative length of a string and its relative frequency with respect to the other string of the consonant

⁷ Claude V. Palisca, "Scientific Empiricism in Musical Thought," in *Seventeenth Century Science and the Arts*, ed. Hedley H. Rhys (Princeton: Princeton University Press, 1961), pp. 104-110 [now in his *Studies in the History of Italian Music and Music Theory* (Oxford: Clarendon Press, 1994), pp. 200-235], Cohen, *Quantifying Music*, pp. 75-78; see also Palisca, "The Science of Sound and Musical Practice," in *Science and the Arts in the Renaissance*, ed. John W. Shirley and F. David Hoeniger (London: Associated University Presses, 1985), p. 67.

pair. The shorter of the two string lengths sounding a fifth, for example, has a length that is two to the longer's three and a frequency that is three to the longer's two. So the characteristic number for this consonance is six, the product of two and three (for the shorter string) or three and two (for the longer.)

H. F. Cohen has observed that the table shows a continued fascination with the formal properties of numbers; Benedetti's purpose in laying it out seems to have been to exhibit that successive numbers in the list are themselves in ratios corresponding to the traditional number ratios of the consonances.⁸ Rather than dismissing the "numerological" interpretation of those ratios in favor of a physical correlation with the physics of sound production, he found a new way of exhibiting their immanence, not only in consonances themselves but also in the mutual relations of consonances. Nonetheless, the interpretation of consonance as relying on the coincidence of pulses opened up the possibility of shifting the foundations of acoustical harmony from numerical formalism to mechanics.⁹ That Benedetti appears to have seen his idea as a way of exploring the role of number in music at a deeper level, however, signals a parallel implication: the coincidence theory might serve as a means of shifting to mechanics the foundations of numerical formalism itself.

By the 1630s, and probably independently of Benedetti's work, the use of vibrations and the coincidence of pulses as the basis of musical harmony had found its way into the writings of Beeckman, Galileo, Descartes, and Mersenne.¹⁰ D. P. Walker's observation that the coincidence theory was "compatible" with the arithmetical theories of the Pythagoreans and Zarlino hints at the implications for number harmony.¹¹ By lending physical intelligibility to numerical ratios previously regarded as abstract formal causes, the theory absorbed the techniques and arithmetical assumptions of its predecessor. Anyone who lacked an interest in retaining Pythagorean ratios and harmonic proportion had no reason to adopt it; Simon Stevin, for instance, could have found no more merit in the vibrational approach than in the Pythagorean. Mersenne, however, committed to just consonances and the mathematical apparatus of harmony, incorporated it into a renova-

⁸ Cohen, *Quantifying Music*, pp. 76-77 (differing from Palisca's interpretation.)

⁹ Given Cohen's convincing reading of the evidence, Palisca seems to be mistaken in imputing awareness of this possible implication to Benedetti himself.

¹⁰ Cohen, *Quantifying Music*, chapter 2 and, on Beeckman, pp. 116-161, esp. 127-129. Cohen characterizes Beeckman's "regularity" theory as slightly different from Benedetti's, Galileo's, Descartes's and Mersenne's "coincidence" theories: is focused on regularities in "sound-silence" patterns rather than frequency of coincidence of pulses; it translated readily into a coincidence theory, however, and the similarities seem more important than the differences.

¹¹ Daniel P. Walker, *Studies in Musical Science in the Late Renaissance* (London: The Warburg Institute, 1978), p. 13.

tion of the theory of music that had answers to Vincenzo Galilei and firm arguments against regarding temperament, as anything other than a means of approximation.

The force of Galilei's objections derived from the lack of grounds for treating string lengths as any more intimately related to the nature of sound than string tension (or the length of pipes.) Since string lengths, contrary to Pythagorean legend, seemed to provide the only direct manifestation of the simple ratios, retention of the latter's preeminence became problematic. No doubt the difficulty might partly have been circumvented by noting that in Galilei's own account the relationships of the other variables relied on compounds of the string-length ratios. But with no explanation of what that meant, the theoretical structure would have remained unsatisfactory. Mersenne found in the coincidence theory a basis for treating one particular physical parameter of sound production, frequency of vibration, as privileged and prior to all others. This parameter had the great advantage of yielding ratios effectively identical to the traditional ones. The attractions of the coincidence theory were therefore considerable, but if it were to do its job of underpinning the theory of music in a properly scientific way, it needed independent support. To make the new conception of consonance plausible, Mersenne attempted a demonstration of the central proposition that the frequency of a string's vibration was inversely proportional to its length.

Benedetti had attempted no proof at all. The doctrine that longer strings vibrate more slowly and emit lower notes dated from antiquity, and Benedetti's assumption of strict inverse proportionality clearly derived from that commonplace; moreover, as he merely threw out the idea in a letter, a rigorous formulation ought not to be expected. In *Quaestiones in Genesim* Mersenne had devoted a column or so to the matter, principally referring to Boethius, but did not go beyond stressing the reliance of pitch on the "velocity" of strings (and the size of pipes, especially the trachea) and observing that, "caeteris paribus," the longer the string, the lower the note.¹² He made no attempt in *Quaestiones* to establish any strict proportional relationship,¹³ and there is no reason why he should have done so: he learned of the coincidence theory only in 1629, from Isaac Beeckman; before that date, little of importance rested on the relationship of frequency to length.¹⁴

¹² Marin Mersenne, *Quaestiones celeberrimae in Genesim* (Paris: S. Cramoisy, 1623), col. 1559; see also Cornelis De Waard's note in Mersenne *Correspondance*, ed. De Waard et alii, 16 vols. (Paris: Beauchesne (vol. 1); Presses Universitaires de France (vols. 2-4); CNRS (vols. 5-) 1932), 1:136, n. 1.

¹³ Contrary to De Waard's implication in Mersenne *Correspondance*, 1:136, n. 1.

¹⁴ With one minor exception: in *Traité*, pp. 394-395, Mersenne's comparison of the speeds of weights on the ends of a balance with the speeds of vibrating strings does imply a

Beeckman had invented a demonstration of the required frequency-to-length relationship in 1614 or 1615, recording it in his *Journal*.¹⁵ He sent a version of it to Mersenne fifteen years later,¹⁶ and it appears, unattributed, as one of the fundamental theorems in *Harmonie Universelle*: “the ratio of the number of returns of all kinds of strings is the inverse of their lengths.”¹⁷ Mersenne there describes the movement of a displaced string as a kind of violent motion comparable to the throwing of a stone, and the demonstration of the theorem relies on an idealized model in which the initial force acting on the string at the moment of its release directly determines the string’s subsequent speed.

Consider two strings AB and AE of equal tension (Figure 1). If AB is pulled sideways so that its center is now at C, and AE is similarly displaced by stretching to D, the tensions on the two strings, now ACB and ADE, remain equal because they form similar triangles. The forces tending to return them to their initial undisplaced states are taken to be directly proportional to the string tensions, so that they too are equal; hence, the argument runs, the speeds of the two strings upon release will also be equal. Since point D is displaced only half as far as point C but returns with the same speed, the shorter string must perform its oscillations about center-line AE in half the time required by the longer string about AB; the frequency of vibration is therefore in inverse proportion to string length. Mersenne confirms the conclusion by considering a case in which string AB is displaced only half its previous distance, to point M (Figure 2), giving it the same initial amplitude as AE. Then, he says, the tension on AMB is only half that on ADE, “as it is easy to conclude by the proportion of triangles.” Hence, its starting speed at M is only half that of AE starting at D, and the relative frequencies remain unaltered.¹⁸

strict inverse proportionality of length to frequency; there is no attempt at a demonstration of this assumption, however.

¹⁵ Reprinted in Mersenne *Correspondance*, 2:234-235. See Dostrovsky, “Early Vibration Theory,” pp. 184-185; Cohen, *Quantifying Music*, pp. 123-124, and 197-200 on Mersenne’s indebtedness to Beeckman. For Beeckman’s work on vibrating strings and his version of the coincidence theory, see (apart from Cohen’s extensive treatment) Klaas van Berkel, “Beeckman, Descartes et ‘la philosophie physico-mathématique,’” *Archives de philosophie* 46 (1983): 620-626, esp. 624-626, emphasizing music theory as the central feature and exemplar of Beeckman’s “physico-mathematics;” Frédéric de Buzon, “Descartes, Beeckman et l’acoustique,” *Archives de philosophie* 44 (1981), Bulletin cartésien X, pp. 1-8; idem, “Science de la nature et théorie musicale chez Isaac Beeckman (1588-1637),” *Revue d’histoire des sciences* 38 (1985): 97-120.

¹⁶ Mersenne *Correspondance*, 2:231.

¹⁷ Mersenne, *Harmonie Universelle*, “Des mouvemens des chordes,” pp. 157-158.

¹⁸ *Ibid.*; note that my labeling of the diagrams differs from Mersenne’s for the sake of clarity.

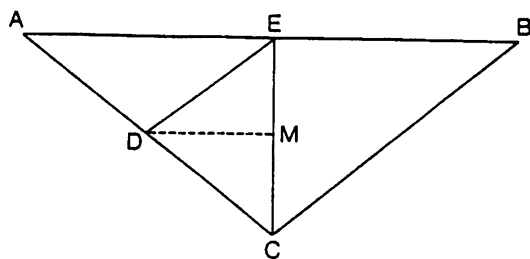


Figure 1

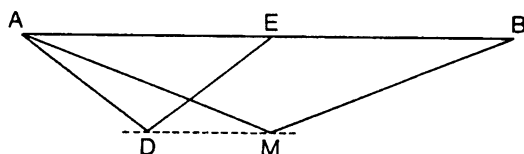


Figure 2

Mersenne's presentation of Beeckman's proof elaborates it considerably and draws in assumptions and implications lacking in the original. The proof therefore takes on a form in *Harmonie Universelle* that must be regarded as Mersenne's own. Page upon page of similar analyses follow, investigating variant cases and examining changes in speed during the course of an oscillation, and the techniques applied derive from those used in the original proof. Thus Mersenne maintained his Aristotelian equation of force and speed: the force tending to return a string to its position of rest is directly proportional to the displacement; therefore, so too is the speed of the string upon release. Moreover, Mersenne's subsequent consideration of a string's variation in speed after release confirms that this relation between force and speed holds generally, not merely at the string's initial release. Still adhering to the conceptualizations informing his discussions of the balance in *Traité de l'harmonie universelle*, Mersenne did not see the initial displacement alone as directly determining the subsequent speed of

the string.¹⁹ Instead, he envisaged a linear deceleration as it moved towards its central position of equilibrium, because the force impelling it back would itself decrease linearly. He compares the motion to that of a violently propelled missile: "Missiles that are moved violently go so much more slowly as they are farther from their origin, that is, from the force by which they have been thrown," just as the displaced string slows in proportion to its displacement. As the force decreases, so too does the speed.²⁰

In remaining true to the mechanical assumptions of the peripatetic tradition, however (and this despite the important role of Galileo's work elsewhere in *Harmonie Universelle*), Mersenne created problems for himself. His idealized model of the behavior of vibrating strings failed to explain why, as is patently and by definition the case, such strings move back and forth rather than coming to rest immediately. If the speed of a string were truly proportional to its displacement, it should slow in a linear fashion upon release, reaching a velocity of zero at the central position of equilibrium.

Mersenne addresses the problem after considering the phenomenon of the decay of oscillation. It appears, he says, that the string undergoes natural motion towards its "center," the position of equilibrium, and then violent motion away from that center as a result of the "impression" it has by that time acquired. He admits, however, that this interpretation presents certain difficulties. The first is that it requires the string to accelerate in proceeding from the extreme to the central position. The second "consists in knowing why the string does not stop in [the center], since it seems that it has no other design than to return to its center."²¹ The first point confronts two kinds of objections, since "experience and reason"—the one term referring to Mersenne's experiments with thousand-foot ropes and the other to the sort of analysis described above—

¹⁹ Beeckman made the tacit assumption that the string continued throughout its passage with the same speed as it had on release.

²⁰ Mersenne, *Harmonie Universelle*, "Des mouvemens des chordes," p. 158. Although Mersenne never committed himself as to why a missile continues to move after its release by the mover, the evidence here suggests that he thought in terms of a self-dissipating impetus—despite his apparent acceptance at various times of Galileo's quasi-inertial ideas, first in the *Les mechaniques de Galilée, mathématicien et ingénieur du Duc de Florence* (Paris: J. Guénon, 1634; critical ed. by Bernard Rochot, Paris: Presses Universitaires de France, 1966), version of *Le meccaniche*. For one treatment (among many) of the impetus theory, see Maurice Clavelin, *The Natural Philosophy of Galileo*, trans. A.J. Pomerans (Cambridge, Mass.: M.I.T. Press, 1971), pp. 91-99.

²¹ Mersenne, *Harmonie Universelle*, "Des mouvemens des chordes," p. 161.

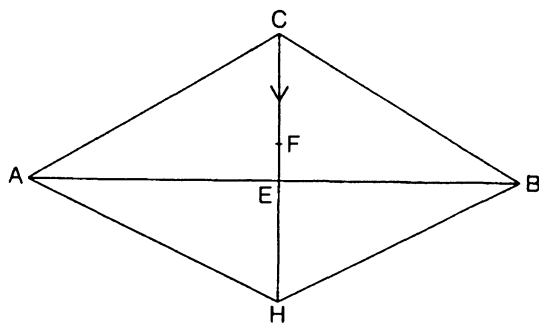


Figure 3

make me conclude that point C of the string (Figure 3) goes always diminishing its speed from C as far as H, for since it only returns because of the violence that stretches it, it ought to return so much the faster the more it is stretched: which I demonstrate in this way. When one draws it only as far as F, or to whatever point one wishes between F and E, it takes as long a time to perform its oscillation [*tour*] as when it is drawn as far as C, or farther, which cannot happen without its going so much the more slowly as it is drawn less and consequently less subjected to violence [*violente*]: now, this violence is so much the less as the point C approaches E, in which it is no longer subjected to violence, whence it follows that it ought to go less fast in proportion as it advances towards E, at which it would rest if the air which surrounds ACB didn't push it still towards H.²²

Mersenne simply denies that the string accelerates towards the equilibrium position.²³ Instead, he reiterates that speed is proportional to displacement and suggests a way out of the apparent dilemma he has created: the string, he now proposes, continues on past the center because of air disturbance. He expands on the idea in a separate Proposition "to explain why the string which returns from the place to which it is drawn passes several times through its center without stopping there." As Mersenne remarks, "we seek a very obscure reason for a very evident effect." Indeed,

²² Ibid., p. 162. It is important to use Mersenne's own corrected copy of *Harmonie Universelle* (the one reproduced in facsimile; see note 6 above) throughout this proposition because of systematic labeling errors in the original text. The similarities between Mersenne's and Aristotle's explanations of the air's role in the motion of projectiles are especially striking because the latter's had been explicitly applied to vibrating strings by Jesuit philosophers: see William A. Wallace, *Galileo and His Sources: The Heritage of the Collegio Romano in Galileo's Science* (Princeton: Princeton University Press, 1984), p. 192.

²³ Mersenne never himself calls it an "equilibrium position;" he always calls it a "center," explicitly by analogy with a gravitational center.

he continues, "it seems to me that to give the reason for this phenomenon it would be necessary to know [*cognoistre*] the different plays of the air, and the different impressions that it makes on the string it repulses."²⁴ The air, he decides, adds a new force to that which returns the string to its center.²⁵ He is unable to be more precise.

Mersenne effectively admits his ultimate inability to accomplish a satisfactory theoretical account of vibrating strings when, after giving this sketchy explanation of perhaps the most basic aspect of vibration, he canvasses a couple of incompatible alternatives. "One can also say that whatever has once started to move, with whatever movement it be, would move eternally if not for the resistance of the air;" perhaps, then, in the absence of air resistance, not only would the string continue to vibrate, but there would be no decay in amplitude. Or else, Mersenne continues, since the string actually does move in the air, one can "imagine" that it moves back and forth for as long a time as it would continue moving if projected freely in a straight line so as to receive the same initial "impression." These remarks, little more than afterthoughts, clearly go against the whole thrust of Mersenne's previous analyses, and he seems in consequence to have thought it wise to emphasize again what he considered to be the most important point: "One should not, however, neglect the reason arising from the effort which each part of the string makes to regain its place and situation, which serves it like gravity [*pesanteur*] to weights, to return to its center E."²⁶

Mersenne's examination of the mechanics of vibrating strings—built on analogies with the behavior of weights, considered along lines laid down in the *Mechanica*—failed to support adequately the contention that frequency and string length were inversely proportional. Mersenne nonetheless accepted its truth; he even used it to determine the absolute frequencies of particular notes by extrapolating from very long strings, the oscillations of which could be counted, to very short strings of the same tension.²⁷ Beeckman's putative demonstration helped to render the relationship more plausible but clearly did not provide the reason for Mersenne's initial acceptance of it. A similar state of affairs holds in the case of Mersenne's acceptance of and argument for the isochronism of vibrating strings. Following a suggestion from Descartes, Mersenne maintained that since the note produced by a string remains of the same pitch even while the amplitude of vibration decays, the frequency evidently stays constant. However, this presupposes that pitch is indeed a direct function of fre-

²⁴ Mersenne, *Harmonie Universelle*, "Des mouvemens des chordes," p. 165.

²⁵ *Ibid.*, pp. 165-166.

²⁶ *Ibid.*, p. 166.

²⁷ See Dostrovsky, "Early Vibration Theory," pp. 197-198; and Hunt, *Origins in Acoustics*, pp. 90-94.

quency, a claim itself resting on a tacit acceptance of the isochronism of vibrating strings.²⁸ No mystery attaches to Mersenne's position, of course: he assumed without rigorous proof those things necessary to establish the coincidence theory of consonance because that theory offered the best grounds on which to defend the traditional mathematical basis of harmony.

After a long discussion of the octave in *Harmonie Universelle's* book "Des consonances," Mersenne gets down to business with Proposition XVI, which discusses in conventional terms the division of the monochord to produce the fourth, the fifth, and their concomitant Pythagorean intervals.²⁹ The succeeding proposition, however, addresses the physical nature of the fifth:

This consonance, which the Greeks call *Diapente* because of the five sounds [i.e., notes] that it contains, is composed of two movements, of which one hits [bat] the air twice while the other hits it three times: thence it is that the string that is so divided that it leaves three parts on one side and two on the other produces the fifth, inasmuch as the side of three parts hits the air twice while the other, which only has two parts, hits it three times, since the number of strokes [battements] is reciprocal to the length of strings, as I have demonstrated elsewhere.³⁰

Even had he possessed a less problematic demonstration of the crucial frequency/length relationship, Mersenne would still have had no physiological grounds for supposing that the regular concurrence of sound pulses would produce the sensation of consonance. In fact, the structure of his commitment coordinates around the original Pythagorean ratios themselves. If one were already disposed to regard as significant those string-length ratios that correlated so neatly with consonant intervals (as Stevin and others were not,) one might tend to identify ratio and consonance, taking the ratio to express something essential about the consonance. Then, even if the ear found perfectly pleasing a fifth with a ratio slightly different from 3:2, the harmony of the precise ratio would be regarded as more exact. Mersenne adhered to just such a position, and by developing a version of Beeckman's coincidence theory, itself based on a mechanical conception of consonance (justified by the classical association of sound with disturbances in the air,) he found a way of squaring Galilei's findings with Zarlino's consonant ratios.³¹ Rather than being transcendental ratios in-

²⁸ See Dostrovsky, "Early Vibration Theory," p. 185, for Mersenne's argument.

²⁹ Mersenne, *Harmonie Universelle*, "Des consonances," p. 60.

³⁰ Ibid.; see also Palisca, "Scientific Empiricism," pp. 110-112.

³¹ Dear, *Mersenne*, chapter 5, details Mersenne's use of Galilei's findings on the relation between pitch and string tension to argue against Robert Fludd in *Traité*. Mersenne had already referred to Galilei's work in *La vérité des sciences contre les septiques ou*

stantiated in all variables of sound production, they became ratios of vibrational frequencies standing at the heart of a new musical, or acoustical, program of mechanistic research. This program, pursued in *Harmonie Universelle*, aimed at discovering how vibrational frequency itself related to the physical variables of sound production and how those relationships thereby embodied the mathematical harmonies expressed in sound. The periodic coincidence of pulses surely caused the sensation of consonance, therefore; that way, music remained mathematical—or, in Augustine's sense, rational—and at the same time provided a technical means of displaying the harmonies that governed all bodies in motion and at rest.

Vibrational frequency was inversely, not directly, proportional to string length, and its use consequently resulted in an inversion of ratios: the fifth, for instance, became associated with a 2:3 ratio of frequencies instead of a 3:2 ratio instantiated in string lengths. Because Mersenne adopted the vibrational coincidence theory as a way of retaining the Pythagorean ratios in music, however, he played down the importance of the change.

It's necessary to remark once and for all that it makes no difference whatever whether the smaller or greater term of the ratios to express the consonances goes first; that is, it is as true [*veritable*] to say that the ratio of the octave is subduple [i.e., 1:2], and that that of the fifth is sub sesquialterate [2:3],³² as to say that the former is duple and the latter sesquialterate, although this second way favors the length or thickness [*grosueur*]³³ of strings... But if one considers the vibrations of strings, the greater [i.e., longer string] ought to be signified by the lesser number, since it vibrates more slowly, and consequently the ratio of the octave will be subduple when one starts with the large string, *although one can always retain the duple ratio for greater ease, and to accommodate oneself to ordinary usage, and to the positions of the ancients*. [My emphasis]³⁴

Proposition XIII of the “livre des dissonances” proclaimed that “there is no difficulty in the theory of music, and all the consonances, dissonances, songs, and concerts are made solely by the addition or subtraction of strokes [*battemens*] of air.”³⁵ In reducing the theory of music to mechanics, Mersenne succeeded in retaining the traditional Pythagorean analysis and overcoming the “difficulties” that had threatened it.

Pyrrhoniens (Paris: Toussaint du Bray, 1625; reprint ed., Stuttgart-Bad Cannstatt: F. Fromman, 1969), pp. 617-618. Galilei's continued use of numerical ratios clearly had value for Mersenne.

³² See Mersenne's explication of these terms for ratios in *La vérité*, pp. 320-324.

³³ Dostrovsky, “Early Vibration Theory,” p. 186, explicates Mersenne's use of this word.

³⁴ Mersenne, *Harmonie Universelle*, “Des consonances,” p. 61.

³⁵ *Ibid.*, “Des dissonances,” p. 137.

Sigalia Dostrovsky has described Mersenne's exposition in *Harmonie Universelle* of what have become known as "Mersenne's Laws" governing the frequency of vibrating strings. She remarks that Mersenne investigated and refined these relationships by experiment but did not himself originate them; she then examines a peculiarity of the rule on string tension. Mersenne says that to tune identical strings an octave apart, the ratio of tensions, or affixed weights, should be 4:1, "inasmuch as the weights are in a doubled ratio [i.e., square] of the harmonic intervals."³⁶ However, he immediately proceeds to warn that in order to make the interval accurate, the ratio should in practice be $4\frac{1}{4}$:1. As Dostrovsky observes, this correction, apparently intended to apply generally, is clearly empirical. "It is interesting," she continues, "that Mersenne divided his empirical result into two components: a 'law' (rule 1) and a 'correction' (rule 2). What he chose to call the law happens to have been correct, but one wonders how he knew. Was it physical intuition or a Pythagorean confidence in the importance of small whole numbers?"³⁷ We can now answer that question. It was the latter.

The Mechanization of Music

Mersenne used mechanics to explain musical harmony. In so doing, however, he necessarily presupposed that at a deeper level, harmony was immanent in mechanics itself, as indeed in all of Creation. He had already exercised that presupposition in *Traité de l'harmonie universelle*, prior to his acquaintance with the possibility of a mechanical "saving of the phenomena" in music. Book 2 of the *Traité* attempts to illustrate the ways in which "consonances are found in all the parts of this universe."³⁸ Mersenne draws parallels between musical consonance and such diverse things as odors and geometry;³⁹ his discussion of the balance, touched on previ-

³⁶ Dostrovsky, "Early Vibration Theory," pp. 185-187, here referring to Mersenne, *Harmonie Universelle*, "Des instrumens," pp. 123-126, quotation on p. 123.

³⁷ Dostrovsky, "Early Vibration Theory," p. 187. Mersenne himself never makes any terminological distinction between the "law" and the "correction;" indeed, he never uses the term "law" (*loi*) for any physical rule, employing instead the word "rule" (*règle*). For the most recent treatment of "laws of nature" from the Middle Ages to the Scientific Revolution, see Jane E. Ruby, "The Origins of Scientific 'Law,'" *Journal of the History of Ideas* 47 (1986): 341-359; see also John R. Milton, "The Origin and Development of the Concept of the 'Laws of Nature,'" *Archives européennes de sociologie* 22 (1981): 173-195. Dostrovsky's reading remains correct in spirit, however.

³⁸ Mersenne, *Traité*, "Preface" to Book 2, [p. 1]; "Epistre" to Book 2, [p. 4].

³⁹ Some of these parallels, including the comparison with odors, are found in Boethius, *De institutione musica*.

ously, takes place as part of a demonstration that “there is the same ratio of the difference of sounds to the difference of strings considered in their length, as there is of the difference of weights to the difference of their distance from the center of the balance, or the fulcrum of the lever... consequently, sounds can be compared to weights, to statics, to the equilibrium of planes [*l’Isorropique*], and to moving forces.”⁴⁰ Just as a weight becomes more heavy or more powerful the farther it is from the center of a balance, so a uniform string gives forth a lower note the longer it is. Conversely, the sharper the note, the shorter the string and the faster its movement in proportion as the string shortens.⁴¹ “It’s therefore necessary to conclude that just as there is the same ratio of the lesser and greater weights to their greater and lesser distance from the center of the balance, and of these weights and these distances to the speed of their movements, there is also the same ratio of the length of strings to the lowness or height [i.e., pitch] of sounds, and of the movement of the [weights] with the movement of the [strings].”⁴²

Three vital elements of Mersenne’s approach to musical and mechanical problems appear here: the *Mechanica*’s interpretation of the balance; the assumption without proof of the inverse proportionality between frequency and string length that later became crucial for Mersenne’s adoption of the coincidence theory; and an attempt to construe a paradigmatic mechanical situation as structurally equivalent to the production of musical notes. Beeckman’s ideas about the nature of consonance were about to fall on very well-prepared ground.

Mersenne continues with a comparison between the law of the balance and man’s relationship to God, then goes on to consider equilibrium on inclined planes. He manages to find a fairly ingenious musical interpretation. The equilibrium of weights has no parallel equilibrium of sounds in the ratio of the attached weights providing the tension; however, he explains, “if we extend two strings, equal in all respects, on two supports [*chevalets*], and one be drawn by a weight of four pounds on the oblique side of a triangle such as ABC, and the other perpendicularly by a weight of two pounds (Figure 4), these two strings would produce unison, which we can call the *equilibrium of sounds*.”⁴³

⁴⁰ Mersenne, *Traité*, p. 392.

⁴¹ *Ibid.*, p. 394.

⁴² *Ibid.*, p. 395.

⁴³ *Ibid.*, pp. 397-398. Note that ED and EF are assumed to be of equal length here.

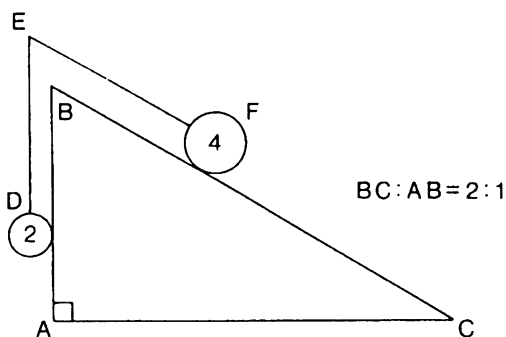


Figure 4

Finally, Mersenne returns to the balance. Following the discussion examined earlier about the effect of a weight's distance from the center on its "force," and of concomitant changes in its "velocity,"⁴⁴ he outlines another correlation with the ratios of music. Referring to Figure 5, he considers "these four numbers 12, 6, 4, 3," which of course correspond to the weights required to counterbalance the twelve units suspended from F at successive multiples of distance EF along the arm EA. The numbers, says Mersenne, "give us the principal consonances of music." Thus "12 and 6 make the octave, 12 and 3 the double-octave [i.e., the fifteenth], 12 and 4 the twelfth, 6 and 4 the fifth, and 4 and 3 the fourth."⁴⁵

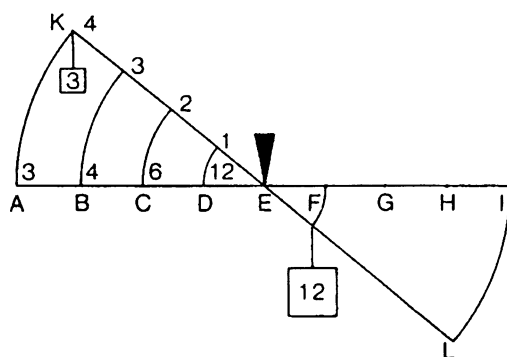


Figure 5

⁴⁴ Ibid., pp. 398-400.

⁴⁵ Ibid., p. 400.

Music represented for Mersenne the most striking evidence of a mathematically and logically ordered universe, and in showing how mechanics participated in its formal structure, he related the behavior of heavy bodies to “universal harmony.” In *Harmonie Universelle* he attempted to save that evidence—both from the sorts of difficulties exploited in La Mothe Le Vayer’s *Discours sceptique sur la musique*⁴⁶ and from the implications of Galilei’s work—by effectively reversing the logical priorities: he used mechanics to guarantee that music embodied rational harmonies in a way similar to that in which, in the *Traité*, he had used music to reveal the harmonies hidden in mechanics.

Nonetheless, music itself remained the touchstone of “universal harmony.” Having finally accepted the doctrine of uniform acceleration in free fall, Mersenne brought out the attractions of its formal characteristics through the presentation of a proposition designed to calculate “from what places weights ought to fall to make such harmonic proportions, and such accords and discords, as one would wish, when they encounter each other.”⁴⁷ Mersenne employs the supposition that, all other things being equal, a falling body produces sound in the ambient air of a pitch proportional to the body’s speed, so that an octave corresponds to a doubling of the speed of fall. On this basis, he determines the various heights from which bodies would have to be dropped, together with the time intervals necessary between releases, for the bodies to come together at the precise moment at which the notes associated with each would combine harmoniously.⁴⁸ Mersenne thus endeavors to match the proportions of free fall with those of musical harmony, and he displays both kinds together in detailed diagrams and tables.⁴⁹ Evidently, free fall exhibited “universal harmony” only so far as it conformed to the pattern presented by music, and Mersenne painstakingly elucidated the relationship, much as he had done for the balance nine years before. He did not merely exploit the theorems of others, however. “Universal harmony” directed his own production of technical mechanical results.

⁴⁶ Mersenne prints this, with his rebuttal, in *Questions harmoniques* (Paris: J. Villery, 1634; reprint ed., Stuttgart-Bad Cannstatt: F. Fromman, 1972), pp. 84–165, although he does not use the coincidence theory in his rebuttal (it does appear, in a different context, on page 19). On this subject generally, see Duncan, “The Tyranny of Opinions Undermined: Science, Pseudo-Science and Scepticism in the Musical Thought of Marin Mersenne” (Diss., Vanderbilt University, 1981), chapter 4, “Scepticism and Musical Science,” pp. 265–332. La Mothe Le Vayer emphasizes Aristoxenian kinds of arguments, and so Mersenne stresses music as an intellectual science.

⁴⁷ Mersenne, *Harmonie Universelle*, “Des dissonances,” p. 134.

⁴⁸ *Ibid.*, pp. 134–137.

⁴⁹ *Ibid.*, p. 136. This was less trivial or contrived than it may seem: the calculated heights of fall and time intervals required to produce consonance display ratios akin to those of music not simply because Mersenne has arranged them that way but because the odd-number rule yields them. Other rules governing fall would not necessarily do so.

In his research, correspondence, and writing on the behavior of vibrating strings, dating chiefly from the late 1620s until the appearance of *Harmonie Universelle*, Mersenne kept in mind an apparently close mechanical analogue: the pendulum.⁵⁰ In 1618 Isaac Beeckman had contemplated the similarity of pendulums and musical strings, and the juxtaposition of the two appears frequently in letters to or from Mersenne in 1629 and the early 1630s.⁵¹ This is true particularly of letters from Descartes, which, because they take the form of answers to Mersenne's endless questions, treat the two phenomena together even though Descartes himself apparently considered them to be quite different. His objections sprang from his apprehension that a different kind of force operated in each case. On one occasion he denied the isochrony of the pendulum, in contrast to vibrating strings, because the weight of a pendulum bob remains constant, whereas the force acting on a plucked string varies with amplitude.⁵² Mersenne, however, tended to accept Beeckman's (and, later, Galileo's) assertion that the period of a pendulum was independent of amplitude and hence that pendulums were isochronous.⁵³ On another occasion, Descartes answered a question about the possibility of a *media quies*, or point of rest, between the outward and inward phases of motion of a vibrating string or between the upward and downward swings of a pendulum;⁵⁴ he protested Mersenne's bracketing together of the two because "the oscillations [*tours et retours*] of a string attached by both ends is one thing, and those of a string attached only by one end, having a weight at the other end, is another."⁵⁵ This terminology seems be Mersenne's own, and it reappears in *Harmonie universelle's* "Livre premier des instruments."

Addressing the problem of determining how long a string continues to vibrate, Mersenne proceeds naturally from musical strings to pendulums.

⁵⁰ For his work on vibrating strings, see Dostrovsky, "Early Vibration Theory," pp. 185-98; Frederick B. Hyde, "The Position of Marin Mersenne in the History of Music" (Diss., Yale University, 1954), chapter 9, pp. 275-303; Pierre Costabel, "Annexe V" to René Descartes, *Règles utiles et claires pour la direction de l'esprit en la recherche de la vérité*, trans. Jean-Luc Marion (The Hague: M. Nijhoff, 1977), pp. 319-322. There is a short discussion in Robert Lenoble, *Mersenne ou la naissance du mécanisme* (Paris: J. Vrin, 1943, 1971), pp. 482-486; relevant letters are noted in *Mersenne Correspondance*, 4:17, 427.

⁵¹ For Beeckman, see *Mersenne Correspondance*, 2:210-211; and for letters juxtaposing pendulums and vibrating strings, see, e.g., *ibid.*, pp. 205-206, 317-319, 346.

⁵² *Ibid.*, p. 346.

⁵³ See notes in *ibid.*, p. 321, and 4:451.

⁵⁴ This was a classical question usually posed with respect to bodies thrown upwards, which slow and then commence to fall. Mersenne addresses it in regard to vibrating strings in *Harmonie Universelle*, "Des mouvemens des chordes," pp. 163-165. Beeckman's ideas required a *media quies* at extreme positions of a vibrating string: see Cohen, *Quantifying Music*, pp. 128-129.

⁵⁵ *Mersenne Correspondance*, 5:126.

The previous proposition had discussed the proportion of diminution of amplitude in a vibrating string, but the present question, says Mersenne, “is much more difficult... inasmuch as one cannot perceive [*on ne peut remarquer*] the last vibration or oscillation [*tremblement ou retour*] of strings, whether they have one of their ends held or whether they are attached by both ends.” Mersenne therefore approximates, noting that although in the former case the oscillations occur much more slowly than in the latter, they also last longer, so that, “perhaps,” the final number of oscillations will be the same for each.

Whence one can conjecture that there is the same ratio of speed of oscillations of the string fixed by both ends to that of the oscillations of the other, as there is of the duration of oscillations of the latter to the duration of oscillations of the former, which will happen if, being held by both ends, it makes go oscillations in the space of a second, and if, being held only by one end, its oscillations last go times as long as those of the other. The same thing must be said of each oscillation of one compared with the other, and consequently the table in the preceding Proposition can serve equally the one and the other string.⁵⁶

(The table to which Mersenne refers details the decay of amplitude of a vibrating string—that is, one “held by both ends”—calculated from the starting point of empirical data.)⁵⁷ Unlike Descartes, Mersenne saw the two cases as modes of the same basic phenomenon: an oscillating string. Descartes considered that the difference in force characteristics argued against any profound similarity, but Mersenne, who knew that the weight of the bob had no effect on a pendulum’s period,⁵⁸ saw a difference only in the precise contrivance of the string’s points of anchorage.

We have seen the crucial importance to Mersenne of the claim that the frequency and length of musical strings were inversely proportional. In the early 1630s no such proportionality had been established for the pendulum. In 1632 Galileo went no further in the *Dialogue* than to make a vague observation that the period decreased with increasing length, while Descartes, analyzing the situation as a variant of free fall, arrived at idiosyncratic conclusions owing to his rejection of the odd-number rule.⁵⁹ Mersenne was

⁵⁶ Mersenne, *Harmonie Universelle*, “Des instrumens,” Proposition XVIII (the first page of which is shown as 45, but the pagination is in disarray.)

⁵⁷ Ibid., facing page to beginning of Prop. XVIII.

⁵⁸ See, e.g., *ibid.*, final paragraph of Prop. XVIII.

⁵⁹ For the state of the question at the time, see notes in Mersenne *Correspondance*, 2:321 and 4:444-446. For Descartes and free fall, see Alexandre Koyré, *Galileo Studies*, trans. John Mepham (Atlantic Highlands, NJ: Harvester Press, 1978), pp. 79-94; Koyré’s account is called into question on good grounds, however, in Stillman Drake, “Free Fall from Albert of Saxony to Honoré Fabri,” *Studies in History and Philosophy of Science* 5 (1975): 347-366, esp. 357-360. For a case of an apparent exception to Descartes’s rejection

the first to state that the period of a pendulum is proportional to the square-root of its length. Alistair Crombie has noted that this rule first appears, without proof or elaboration, in one of Mersenne's "Additions" to *Les mechaniques de Galilée*, in 1634,⁶⁰ and the full exposition presented in various parts of *Harmonie Universelle* two years later still predates any other publication of the relationship.⁶¹ Mersenne's quite thorough explication, in contrast to his approach to free fall, involves little empirical justification, and it displays links with the analogous rule for musical strings.⁶² Since he made no categorical distinction between vibrating strings and swinging pendulums, and since musical harmony integrated with mechanics and thereby with "universal harmony," he apparently saw the pendulum as a natural extension or additional manifestation of the mechanical principles underlying music.

Mersenne's demonstration relied on treating the downward swing of the bob as a case of free fall (see Figure 6). Galileo had compared the arc described by a pendulum to an infinite succession of inclined planes: Mersenne asserted that because bodies descend along all planes of whatever inclination according to the odd-number rule governing free fall, the vertical component of a pendulum bob's descent must increase in the same way. Hence the vertical distance fallen, as in ordinary free fall, is proportional to the square of the time, and so the time of a half-swing is proportional to the square root of the initial height of release. For any given angle of release, that height is itself directly proportional to the string length, from which it follows that the period is proportional to the square root of the length.⁶³

of Galileo's rule, see Antonio Nardi, "Descartes 'presque galiléen,'" *Revue d'histoire des sciences* 39 (1986): 3-16. See also Dear, *Mersenne*, chapter 8, pp. 201-222.

⁶⁰ Crombie, "Mathematics, Music," pp. 299-300; also Alistair C. Crombie, "Mersenne, Marin," in *DSB*, 9:319. Mersenne's statement is in *Les mechaniques*, p. 70 (note misprint giving time ratio as 4:1, an error also found in the original); Rochot did not comment on the significance of this passage in his notes.

⁶¹ See note in Mersenne *Correspondance*, 2:321. Piero E. Ariotti, "Aspects of the Conception and Development of the Pendulum in the 17th Century," *Archive for History of Exact Sciences* 8 (1972): 329-410, deals significantly with Mersenne only on pages 378-379, regarding isochrony.

⁶² See esp. Mersenne, *Harmonie Universelle*, "Du mouvement des corps," pp. 131-135. A full and reliable account is given as Appendix 3 in Mersenne *Correspondance*, 4:444-455. It draws on the *Harmonie universelle* and its contemporary Latin counterpart, Marin Mersenne, *Harmonicorum libri XII* (Paris: G. Baudry, 1648; reprint ed., Genève: Minkoff, 1972), which is a later edition of the work originally issued in two parts. For a comparison of the two editions, see Lenoble, *Mersenne*, p. xxii.

⁶³ There may be a curious connection between Mersenne's derivation using Galileo's law of fall and the origins of that law itself: David K. Hill, "Galileo's Work on 116v: A New Analysis," *Isis* 77 (1986): 283-291, esp. 289-290, suggests that Galileo may have derived the relation $v \propto \sqrt{s}$ from his law of chords, itself related to analysis of pendulum motion.

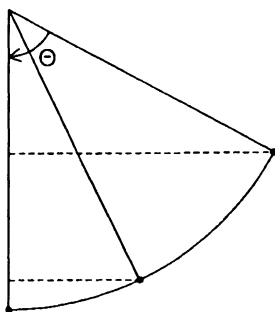


Figure 6

When discussing the behavior of vibrating strings, Mersenne described their tendency to return to the “center” when displaced as being “like gravity to weights.”⁶⁴ In neither case did he think that he could explain the true physical causes at work, but he conceptualized the formal mechanical situations according to the same basic model. The pendulum—a string held at one end—manifested a particular kind of free fall, the appropriate analysis for which isolated the vertical component of motion and treated it as uniform acceleration downwards. The movement of a vibrating string—a string held at both ends—was also a kind of “natural” motion towards a center, ideally represented by speed decreasing uniformly in proportion to decreasing distance from the central position, although actually occurring as deceleration towards a point somewhat beyond it. The oscillatory motion in both cases resulted from a thwarting of the tendency towards the center, owing to the inelastic properties of the string restraining the pendulum bob’s further descent and making it swing upwards, or to the air reinforcing the musical string’s impetus and making it carry on past its center. The structural similarities stem from Mersenne’s still very Aristotelian mechanics, wherein (as the pamphlet of 1633 speculated) falling bodies must be impelled by a force varying in such a way as to produce uniform acceleration, speed being directly proportional to force, and variation of speed with time being caused by variation of force with distance. On the basis of these conflations, the change in speed of the vibrating string, as the force impelling it to the center decreased linearly, exactly mirrored the change in the unconstrained vertical speed of the pendulum bob as the force generating free fall accelerated it.⁶⁵

⁶⁴ See above, text to n. 26.

⁶⁵ Clearly, the discontinuities of motion involved in both cases never appeared to Mersenne as a problem; there were no reasons why they should have. If one thinks both of

Mersenne investigated vibrating strings in the first place because they produced musical sounds. Beeckman's analysis, and his own elaboration of it, provided a mechanistic grounding for Pythagorean harmony. The techniques serving to mechanize music, since they were designed to retain its existing mathematical character, necessarily served also to establish harmony in mechanics itself. Mersenne's derivation of the pendulum rule exemplifies his search for "universal harmony" and shows how his belief that Creation embodied a rational order implied more than simple encouragement towards mathematical natural philosophy; it also involved the construction and application of specific mathematical and mechanical procedures. Musical strings, pendulums, harmony, and mechanics were inextricably connected in Mersenne's work. At the beginning of *Harmonie Universelle*, following the index, appear three pages that Mersenne filled with small print at the last moment when he discovered that the printer had left some empty space.⁶⁶ They contain material taken from a version of parts of Galileo's *Two New Sciences*, which Mersenne had seen in manuscript not long before.⁶⁷ Two of these pages describe Galileo's account of how pendulums can be used to illustrate the periodic coincidence of oscillations characterizing musical consonances, a topic found in the "First Day" of Galileo's discourses; Mersenne specifies string lengths suitable for revealing them easily to the eye.⁶⁸ Thus, from his hasty perusal of Galileo's new treatise, Mersenne picked out as especially valuable an analogy between pendulums and musical strings that showed, in effect, how both embody harmony. The remaining page of this addition details, as a complement, Galileo's laws of local motion.

The teachings of Saint Augustine sanctioned Mersenne's attempts to find manifestations of "wisdom," number and harmony, in the physical world. Mersenne wished on that basis to extend the scope of the mathe-

models of reflection in optics and analogous treatments of bodies rebounding from solid surfaces (seen together in, e.g., Descartes's *Dioptrique*), one realizes that discontinuities of motion were routinely implicated in the mathematical sciences of the period. On this point, see also Drake, "Free Fall," which explicitly discusses discontinuous accounts of the mechanism of natural acceleration.

⁶⁶ As mentioned on the first page of the three.

⁶⁷ See Crombie, "Mersenne," p. 319. For a discussion of Mersenne's acquaintance with the *Two New Sciences* during the final stages of composition of the *Harmonie Universelle*, see Marin Mersenne, *Les nouvelles pensées de Galilée* (Paris: H. Guéron, 1638-1639), introduction to the critical edition by Pierre Costabel and Michel-Pierre Lerner (Paris: J. Vrin, 1973), pp. 20-28.

⁶⁸ On Galileo and the musical material of the *Two New Sciences*, see Walker, *Studies*, pp. 27-33; and Cohen, *Quantifying Music*, pp. 85-92, in which the interesting error involved in the comparison is noted on pp. 91-92, drawn from notes to the critical edition of Mersenne, *Nouvelles pensées*. On this point, see also William R. Shea, "Marin Mersenne: Galileo's 'traduttore-traditore,'" *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* 2 (1977), fasc. 1, p. 69.

mathematical sciences, to exploit their usefulness and their solidity, and to uncover causes in physical phenomena to the extent that mathematics could provide them. He adopted Beeckman's term "physico-mathematics" not because he accepted Beeckman's own approach (which in large measure he did not) but because it expressed neatly his own ambitions for a mathematical and empirical approach to nature. Mersenne persisted, despite Galileo, to effect the crucial junction between statics and dynamics, force and speed, using concepts from the peripatetic tradition. With the *Mechanica*'s model problem solutions linking statics to the study of local motion, and with Beeckman's coincidence theory, mathematical regularities could be constructed that connected the science of mechanics (taken as the union of statics and local motion) to the science of music in such a way as to yield results in areas previously the province of physics alone. Without "universal harmony," however, the project lacked any conviction, being no more plausible than scholastic physics without access to essences.

MOVING THE AFFECTIONS THROUGH MUSIC: PRE-CARTESIAN PSYCHO-PHYSIOLOGICAL THEORIES *

Claude Victor Palisca

Beginning around the middle of the 16th century, composers increasingly bent their creative efforts toward moving the affections. Nicola Vicentino early championed this goal. In setting secular poetry, he wrote, “the composer’s sole obligation is to animate the words and, with harmony, to represent their passions—now harsh, now sweet, now cheerful, now sad—in accordance with their subject matter.”¹ Arcadelt and Willaert already in the 1530s and 1540s demonstrated in their madrigals that this could be done. When Francesco dalla Viola, himself a composer, published as *Musica nova* (1559) Adrian Willaert’s collection of secular madrigals and sacred motets composed mostly in the 1540s, he praised the composer’s ability to “make the soul feel, at his bidding, every affection that he proposes to move.”²

Although no one questions the importance of the affections in the music of the Baroque period, scholars have paid comparatively little attention to their role in 16th century music and thought. Yet this is when the vogue of the affections began. The wave of interest had complex causes, a primary one being the revival of classical rhetorical theory. Circumstances created a demand for stirring oratory, from the need for persuasive advocacy in civil society to rousing sermons in Reformation and Counter-Reformation churches. Humanism had made ancient models and instructions in oratory that stressed moving the passions readily available.

German musicologists have shown the greatest interest in the subject of the affections, especially in formulations by Johann Mattheson and his contemporaries in the 18th century. They have tended to project these theories into the 17th century, positing an *Affektenlehre*—a doctrine of the af-

* This essay is drawn from a chapter in Claude Palisca’s book “Music and Ideas in the Sixteenth and Eighteenth centuries,” in publication at the Yale University Press.

¹ Nicola Vicentino, *L’Antica musica ridotta alla moderna prattica* (Rome: Antonio Barre, 1555), Book 3, chapter 15, trans. as *Ancient Music Adapted to Modern Practice*, with introduction and notes by Maria Rika Maniates, ed. by Claude V. Palisca (New Haven: Yale University Press, 1996), p. 150: “il Compositore... sarà solamente obligato à dar l’anima, à quelle parole, & con l’Armonia di mostrare le sue passioni, quando aspre, & quando dolci, & quando allegre, & quando meste, & secondo il loro soggetto.”

² Francesco dalla Viola, Letter of dedication to Alfonso II d’Este, 15 September 1558, in Adrian Willaert, *Musica nova* (Venice: Antonio Gardane, 1559): “che ad ogni sua richiesta fa sentir nell’animo tutti gli affetti, che si propone di muouere...”

fections—that drove composers to channel their expressive powers in ways consistent with such a doctrine.³ Recently George Buelow denied that there was any evidence of an *Affektenlehre* before the 18th century and dismissed the label as an invention of Mattheson's.⁴ I would add that by the time Mattheson published his theories about how to arouse the affections through music, the musical genres and techniques he recommended were no longer in fashion.

Several scholars who have treated the subject acknowledge a foundation in ancient Greek and Roman medicine and rhetoric but otherwise concentrate on the contributions of Descartes, Kircher, and their mostly German followers, including Mattheson. This is true of both the article "Affektenlehre" by Walter Serauky in *Die Musik in Geschichte und Gegenwart*, first edition, 1 (1949-51):113-21, and "Affekt" by Werner Braun in the second edition, Sachteil 1 (1994):31-41.

In this essay I aim to show that there was a substantial body of theory concerning the affections and music before Descartes and Kircher, particularly by Italian authors and one Spanish author. This is not surprising, since it is in Italy that the modern expressive trends of the 17th century first emerged in the madrigals of the *seconda prattica* and in monodies of Caccini, Peri, and Monteverdi. An acute awareness of the affections in Italy in the second half of the 16th century prepared the way for this shift in musical style.

It became common in the 16th century, and remains so today, to think of music as a language of the emotions, yet people did not always believe that the affections were worth communicating. Early Christian and medieval theologians and philosophers deplored the passions as afflictions to be extinguished, not aroused or communicated, and they could buttress this conviction with the authority of Plato, Cicero, and other ancient authors. Cicero, an author widely read in the Renaissance, emphatically denied the passions a place in a healthy mind. Taking a stand consistent with the Stoic philosophers, he called them "disorders" (*perturbationes*) and a principal source of distress (*aegritudo*). Among them he named envy, jealousy, compassion, anxiety, mourning, sadness, grief, fear, shame, rapture, anger, hatred, lust, and longing.⁵ Cicero based his position on the belief that the soul was divided into rational and irrational parts; the irrational, where the

³ Interest in the affections was promulgated by the monumental study of Wilhelm Dilthey in *Weltanschauung und Analyse des Menschen seit der Renaissance und Reformation* (Leipzig: Teubner, 1914; 9th ed. Göttingen, 1987).

⁴ George J. Buelow, "Johann Mattheson and the Invention of the *Affektenlehre*," in *New Mattheson Studies*, ed. George Buelow and Hans Joachim Marx (Cambridge: Cambridge University Press, 1983), pp. 393-407.

⁵ Marcus Tullius Cicero, *Tusculan Disputations*, 4.7-8.

passions arose, should be ruled by the rational part. The last thing one would want to do is propagate the passions through music.

Although Renaissance humanists generally admired Cicero, especially his prose style and his grammatical works, the genial acceptance of the passions by Aristotle and the Epicurean philosophers appealed to some more than the strict discipline of the Stoic philosophers. Lorenzo Valla choreographed his dialogues in *De voluptate* (Concerning Pleasure, 1509) around three major philosophical schools personified by well known living humanists as speakers, a Stoic (Leonardo Bruni), an Epicurean (Antonio Beccadelli known as Panormita), and a Christian (Niccolò Niccoli). Although Valla allowed each to hold his own, he subtly promoted the Epicurean ideal of pleasure—*voluptas*—as the highest good.⁶

If the Stoics elevated the virtues, such as prudence, justice, temperance, and fortitude, Valla raised to equal heights the human emotions and passions. An affection was seen as a movement toward something good for a person and away from what was injurious. The attainment of a good thing brings pleasure. Thus the desire for pleasure manifests the urge for self preservation and procreation. Through the passions we truly partake of nature and life.

The Latin *passio* is a translation of the Greek *páthos*, a suffering, emotion, or passive state, something a person is liable to feel as a passive subject. *Passio* in Christian literature most often applies to the suffering of Christ, for which worshippers feel *compassio*, ecclesiastical Latin for “sympathy.” *Páthos* should be distinguished from the Greek *éthos*, moral character, which music was thought to influence, as, in Plato’s view, the Dorian and Phrygian modes were conducive to good moral character, the Lydian not.⁷ The Latin *affectio*, or rarer, *affectus*, a state of mind or feeling, are nouns derived from the verb *afficio*, to affect, to put someone in a certain state. In English “affection” has generally been preferred to “passion” for a permanent or semi-steady state of the mind or feeling, because it does not so much imply suffering as the result of some action. Both terms imply a persistent sentiment from which one has actively to be removed as opposed to a transitory feeling. “Affection” and “passion” are preferable in English to “affect,” a transliteration of the German *Affekt*, which has modern psychological connotations. *Affectio* and “affection” can

⁶ In a later version published in 1509 under the title *De vero falsoque bono* (Concerning the True and False Good), Maffeo Vegio was the Epicurean, Catone Sacco the Stoic, and A. Raudense the Christian. See the introduction by Maristella de Panizza Lorch to her and A. Kent Hieatt’s edition and translation of this final version in Lorenzo Valla, *On Pleasure, De voluptate* (New York: Albaris Books, 1977) and Lorch’s study, *A Defense of Life: Lorenzo Valla’s Theory of Pleasure* (Munich: Wilhem Fink, 1985).

⁷ Plato, *Republic*, 398e.

also mean a favorable disposition towards someone or something, but that meaning is not relevant to the present discussion.

Those who defended the passions looked to Aristotle, for he recognized their importance to oratory, music, and poetry. The passions could sway judges in a trial, and in his *Rhetoric* Aristotle taught how to arouse and move the passions through oratory. There he defined and treated fifteen affections, among them anger, mildness, love, hatred, fear, confidence, shame, pity, indignation, envy, and emulation.⁸ In *Politics* he dealt with how the passions could be moved and purged through music, and in *Poetics* through tragedy. Among the later rhetoricians, Cicero and Quintilian considered a smaller number of affections and were less concerned with their definition than with their usefulness to oratory.

An eloquent defender of the passions among the followers of Aristotle in the Renaissance was Juan Luis Vives. Born in Valencia probably in 1493 of Jewish parents who had converted to Catholicism, he spent most of his life in self-exile in Bruges, partly in fear of the Inquisition (it had ordered his father executed). In his *De anima et vita* (Concerning the Soul and Life), published in Bruges in 1538 two years before he died, he devotes the entire third book to the passions. The soul, in men as in animals, possesses the faculties of imagination to receive impressions of the senses, of memory to retain these, of fantasy to perfect them, and, finally, of judgment to assess whether a sensed object is congenial or injurious. It is this judgment that arouses the affections. "The critical cognition of the injurious and of the beneficial generates in us a desire for the useful and an aversion and alienation from the injurious and also the movements of the soul that incline us toward a present or future good and away from what may harm us. These movements are called affections or disorders."⁹ The movement that responds to a present good is joy, which when confirmed turns to love. The response to a future good is desire. The movement responding to evil is anger, which when confirmed turns to hate. Present evil leads to sadness, future evil to fear or courage. Where there is no movement as in tranquility and equanimity, there is no passion. In twenty-three chapters Vives describes in detail individual affections and gradations of them.¹⁰

The operations of the soul depend on the senses and the body, and specifically on very thin and clear spirits that evaporate from the blood in the heart and flow to the brain. On the way, the blood mixes with other hu-

⁸ Aristotle *Rhetoric* 2.2-11.1378a-1388b.

⁹ Juan Luis Vives, *De anima et vita*, Book 1, chapter 10, in Vives, *Obras completas*, trans. Lorenzo Riber (Madrid: M. Aguilar, 1948), 2:1172; see also Carlos G. Noreña, *Juan Luis Vives and the Emotions* (Carbondale and Edwardsville: Southern Illinois University Press, 1989), p. 45. Vives, *De anima et vita*, Book 1, chapter 12.

¹⁰ *Ibid.*, Book 3, chapters 2-24.

mors secreted by the pituitary gland (phlegm), the liver (yellow bile or choler), and the spleen (black bile). Distillations of these four humors make up the spirits.¹¹ A healthy person enjoys a balance of the humors, hence an even temperament., Excess of blood in the spirits provokes a sanguine temperament, of yellow bile a choleric one, of phlegm a phlegmatic temperament, and of black bile a melancholic one (see Table).

This doctrine of the spirits, humors, and temperaments, is not far removed from that transmitted by Galen (ca. 130-ca. 200), a Greek physician who practiced in Rome and whose writings, revived in the 15th century, became the foundation of Renaissance medical science. In *On the Passions and Errors of the Soul* (written in Greek), he stated that the three fundamental members of the body, the liver, the heart, and the brain each is dominated by and refines a particular spirit (*pneuma*). The physical spirit (*pneuma physicon*), associated with the liver, controls nutrition, growth, and reproduction. The vital spirit (*pneuma zotikon*), mixed in the heart with inhaled air, conveys heat and life through the arteries. Distilled in the brain, this becomes the animal or psychical spirit (*pneuma psychicon*), which controls the feelings and pleasures and activates the body and the senses by means of canals in the nerves.

The spirits are produced in the organs through the power of the four qualities, warm, cold, moist, and dry, which, Aristotle theorized, animate living bodies. Heat in the veins alters food to produce blood. When nutriment is not in proper proportion, other humors result: yellow bile or choler from disproportionate heat combined with dry conditions, phlegm from insufficient heat and wetness, black bile from cold and dryness. The qualities derive their powers from the four elements, warmth from fire, dryness from air, wetness from water, and cold from earth. (See Table) This theory, Galen admits, was not original but depended on Hippocrates (ca. 460-ca. 377 B.C.), Plato, Aristotle, and many others.¹²

Elements	Qualities	Organs	Humors	Temperaments
Fire	Heat	Heart	Blood	Sanguinous
Air	Dryness	Liver	Yellow bile	Choleric
Water	Humidity	Brain	Phlegm	Phlegmatic
Earth	Cold	Spleen	Black bile	Melancholic

Galen's theories reached most 16th and 17th century readers indirectly. One of the favorite transmitters was the 13th century encyclopedist Bartholomaeus Anglicus. His *De proprietatibus rerum* (On the Properties of

¹¹ Ibid., p. 110.

¹² Galen, *On the Natural Faculties*, trans. Arthur J. Brock (London: William Heinemann; New York: G. P. Putnam's Sons, 1916), Book 2, chapters 8ff.

Things)¹³ was widely read, often in translation. (Batman's English translation, for example, was published in 1582¹⁴ and many times reprinted.)

Bartholomaeus regarded the soul as threefold: vegetable, which enables life but no feeling, as in plants; sensible, which endows life and feeling but not reason, as in animals; and rational, which sustains life, feeling, and reason, as in humans. He elaborated on the generation and composition of the spirits. A spirit is a thin and airy substance that excites the powers of the body to accomplish their actions. Heat boils the blood in the liver to yield this thin vapor, which, refined by the veins of the liver, becomes the *natural spirit*. It spreads to other parts through the pulsation of the arteries, supplying life and pulse, sense and voluntary motion through the nerves and muscles. The heart further purifies this vapor, producing the *vital spirit* which spreads to all parts of the body through the arteries and veins. Still more subtle is the *animal spirit*, generated in the anterior ventricle of the brain, partly disseminated through the sense organs and partly remaining in the same ventricle for the operation of the common sense and imagination.¹⁵

Animal spirit plays an important part in hearing. In a chapter dedicated to this sense (3.18), Bartholomaeus argues that at least four things are necessary to hearing, an efficient cause, a suitable organ, a medium to convey the sound, and a mind intent on hearing it. The efficient cause is the animal faculty of hearing (*virtus animalis audibilis*). The organ is a certain rock-hard or cartilaginous bone (the *os petrosum*) in the ear that is concave, dry, twisted, and hard. It is concave so that it might contain spirit and air. It is twisted so that a sudden strong blow would not hurt the audible spirit, rather permit it to arrive smoothly and delight the hearing. It is hard and dry so that the air may strike it strongly. The medium is the beaten air (*aer percussus*), which enters the orifice and strikes the hard bone that is the first instrument of hearing. A focused mind is necessary, because extending attention to a plurality of things renders it less capable of performing completely the action of the hearing faculty.

Hearing comes about when two nerves issuing from the interior part of the brain carry the animal spirit to the *ossa petrosa*, to which the exterior air communicates the form of a sound. The animal spirit, altered according

¹³ Bartholomaeus Anglicus, *On the Properties of Soul and Body, De proprietatibus rerum libri iii et iv*, ed. from Bibliothèque nationale Ms. latin 16098 by R. James Long (Toronto: Centre for Medieval Studies, 1979). There were eighteen printed editions of the Latin text and translations into six vernacular languages (Introduction, pp. 1-2).

¹⁴ *Batman vppon Bartholome, his booke De proprietatibus rerum* (London: Thomas East, 1582).

¹⁵ *De proprietatibus rerum*, 3.22.

to the properties of the beaten air, returns to the chamber of the phantasy and presents its changed form to the mind.¹⁶

If the ear contains animal spirit, which is thus in immediate contact with the exterior air, sounds can influence the animal spirit and the mind more directly than can objects of the senses of sight, taste, smell, or touch. Thus music has a privileged entry into the soul, making it an ideal link to the body.

Among those who seized upon this juncture was Marsilio Ficino. Although he did not recognize the common threefold division of the spirits into natural, vital, and animal, he understood the spirit as a vapor of the blood that is pure, subtle, hot, and clear. "Formed from the subtler blood by the heat of the heart, it flies to the brain, and there the soul assiduously employs it for the exercise of both the interior and exterior senses."¹⁷ Song, being composed of mental images as well as sounds, through the junction of the external air and the spirit, finds its way from the fantasy of the singer to that of the hearer and moves the hearer to the emotion expressed by the singer, communicating as well the meanings conveyed by the words.¹⁸ Sounds, moreover, arising from the movement of air, are able to transmit movement, something the other senses cannot. By comparison, the sight delivers static images, while taste, smell, and touch have no intellectual content.

Musical sound by the movement of the air moves the body: by purified air it excites the aerial spirit which is the bond of body and soul: by emotion it affects the senses and at the same time the soul: by meaning it works on the mind: finally, by the very movement of the subtle air it penetrates strongly: by its contemperation it flows smoothly: by the conformity of its quality it floods us with a wonderful pleasure: by its nature, both spiritual and material, it at once seizes and claims as its own, man in his entirety.¹⁹

¹⁶ The above is a paraphrase of the first part of Bartholomaeus' chapter (3.18) on the hearing. The rest of the chapter deals with afflictions and injuries to the organ of hearing.

¹⁷ Ficino, *De triplici vita*, in Marsilio Ficino, *Opera omnia* (Basle: 1576), p. 496, trans. Daniel P. Walker, *Spiritual and Demonic Magic from Ficino to Campanella* (London: The Warburg Institute, 1958), p. 3: "ex subtiliori sanguine procreatus volat ad cerebrum, ibique animus ad sensus tam interiores, quam exteriores exercendos assidue utitur."

¹⁸ Echoes of Ficino's ideas and interpretations of Plato abound in Gioseffo Zarlino's *Le Istitutioni harmoniche* (Venice, 1558), for example in Book I, chapter 4. On the other hand, his account of how music moves the passions in II, 7 and 8 is eclectic and depends as well on Galen, Aristotle, Horace, and Augustine. For a different view see Sabine Ehrmann, "Marsilio Ficino und sein Einfluß auf die Musiktheorie," *Archiv für Musikwissenschaft* 18 (1991): 234-249, especially 244-245.

¹⁹ Ficino, *Commentarium in Timaeum*, 100.28, in *Opera omnia*, p. 1453, trans. Walker, *Magic*, p. 9: "Concentus autem per aeream naturam in motu positam movet corpus: per purificatum aerem concitat spiritum aereum animae corporisque nodum: per affectum, afficit sensum simul & animum: per significationem, agit in mentem: denique per ipsum subtilis aeris motum, penetrat vehementer: per contemperationem lambit suaviter: per

Gioseffo Zarlino, the most widely read music theorist of the mid-16th century, exemplifies the impact that the doctrine of the qualities, humors, and affections had upon musical thought. His chapter (Part 2, chapter 8) in *Le Istitutioni harmoniche* of 1558 bears the title: "How melody and rhythm can move the soul, disposing it to various affections and induce in a human being various behaviors."

It is not a great wonder that some deem it strange that harmony and rhythm (*numero*) should have the power to dispose and induce various passions in the soul, because these are undoubtedly extrinsic things that have little to do with human nature. But, truly, it is only too evident that they do, for the passions are located in the sensitive corporeal and organic appetite as its true subject. Each of these passions consists of a certain proportion of hot, cold, humid, and dry according to a certain material distribution. When one of these passions is active, one of the named qualities prevails. Thus humid heat predominates in anger, inciting its arousal; cold dryness predominates in fear, constringing the spirits. The same happens in the other passions, which are generated by the dominance of one of the named qualities. Undoubtedly these passions are reputed to be vices in moral persons unless the excesses of the qualities are reduced to a certain moderation through a mediating operation that may be said to be virtuous and laudable.

The [ancient] harmoniae had a natural capacity to do this. So it is said that the Phrygian harmonia naturally excites anger and is affective, that the Mixolydian makes a person grieving and withdrawn, and that the Dorian is more stable and of strong and temperate moral characters and is intermediate between the two [the Phrygian and Mixolydian]. This is evident in the different mutations of the soul when these harmoniae are heard. From this we may conclude that the very proportions that are found in the qualities named are found also in the harmoniae. Of each effect there is a proper cause, and this is the proportion in the qualities and in the harmoniae. Therefore we may say that the very proportions of the qualities that cause anger or fear or other passion, these same proportions are found in the harmoniae and cause them to incite similar effects... So we can easily understand how the harmoniae can move the soul and dispose it to various passions.²⁰

conformem qualitatem mira quadam voluptate perfundit: per naturam tam spiritalem quàm materialem, totum simul rapit & sibi vindicat hominem."

²⁰ Zarlino, *Le Istitutioni harmoniche*, Book II, chapter 8, pp. 73-74: "Non sarebbe gran meraviglia, se ad alcuno paresse strano, che l'Harmonie, & il Numero havessero possanza di dispor l'animo, & indurlo in diverse passioni; essendo senza alcun dubbio cose estrinseche, le quali nulla, o poco fanno alla natura dell'huomo: Ma in vero è cosa pur troppo manifesta, che l'hanno: percioche essendo le passioni dell'animo poste nell'appetito sensitivo corporeo, & organico, come nel suo vero soggetto; ciascuna di esse consiste in una certa proportione di caldo & frigido; & di humido & secco, secondo una certa dispositione materiale; di maniera che quando queste passioni sono fatte, sempre soprabonda una delle nominate qualità in qualunque di esse. Onde si come nell'Ira predomina il caldo humido, cagione dell'incitamento di essa; così predomina nel Timore il frigido secco, il quale induce il ristrengimento de i spiriti. Il simile intraviene etiandio nelle altre passioni, che dalla soprabondanza delle nominate qualità si generano. Et queste passioni tutte senza dubbio sono riputate vitiose nell'huomo Morale; se non che quando tali

Neither Ficino nor Zarlino described how the movements of the air produced the affections. Girolamo Mei (1519-1594), a classical philologist and author of treatises on Tuscan prose and poetry, took a step in this direction when he analyzed the effect of pitch accent in Tuscan prose in the 1540s. He attributed the emotional effect that speech had on the listener partly to the height or lowness of the reciting voice's pitch.

Since in speech we hear prominently and principally the voice's height and lowness—differences befitting it, originating in diverse qualities of movement—the sense organ, when struck, must hear them according to those qualities from which they arise and must represent images altogether resembling these to the faculty that is their natural judge. Height of pitch, being generated by the force and speed of motion (as musicians clearly demonstrate...), of necessity must have the power to express and make felt only qualities of affection similar and corresponding to the nature of that [motion] and entirely different from low pitch, whose mother, as it were, is slowness and sluggishness. Consequently, as much as one of these is heard to surpass the other, that much more will the quality of one be represented than the quality of the other. When we hear the two as equivalent, a median or temperate disposition will appear, because every resemblance, stirring almost naturally passions similar to itself, always moves in the subject born to receive them affections that correspond, in proportion to its potential.²¹

soprabondanze si riducono ad una certa mediocrità, nasce una operation mezzana, che non solo si può dire virtuosa, ma anco lodevole. Questa istessa natura hanno etiamdio le Harmonie; onde si dice, che l'Harmonia Frigia hà natura di concitar l'ira, & hà dello affettuosio; & che la Mistalidia fa star l'huomo più ramarichevole, & più raccolto in se stesso; & che la Doria è più stabile, & è molto da costumi da forti, & temperati: conciosia che è mezzana tra le due nominate & questo si vede nella diversa mutatione dell'animo, che si fa quando si ode coteste Harmonie. Per la qual cosa potemo tener per certo, che quelle proportion istesse, che si ritrovano nelle qualità narrate, si ritrovano anco nelle Harmonie: essendo che di un solo effetto non gli è se non una propria cagione, la quale nelle qualità già dette, & nelle Harmonie; è la Proportion. La onde potemo dire che quelle istesse proportioni, che si ritrovano nella cagione dell'Ira, o del Timore, o di altra passione nelle sopradette qualità; quelle istesse si ritrovino anco nell'Harmonie, che sono cagioni di concitare simili effetti... facilmente potemo conoscere, in qual modo le Harmonie possino muover l'animo, & disporlo a varie passioni."

²¹ Mei, *Della compositura delle parole*, Florence, Biblioteca nazionale centrale, MS Magl. VI.34, fols. 61v-62r: "Poiche adunque nel' parlar si senton' manifestamente e principalmente l'acutezza e grauità della uoce, sue proprie differenze, le quali hanno per la quasi fonte diuersa qualità di mouimento, di necessità, fà di mestiere che il sensorio, che percosso le dee sentire secondo la uirtù, onde esse hanno origine, quando egli le sente, ne rappresenti alla potenza, che naturalmente n'è giudice, concetto tutto simigliante. L'acutezza adunque essendo (come apertamente dimostrano i musici, e' come poco sopra incidentalmente s'è detto) generata dalla potenza e velocità del mouimento, necessariamente non può hauer' uirtù senon' d'exprimere e' far' apparir' qualità d'effetto simile e' rispondente alla natura di quello, e' interamente diuersa dalla grauità, la cui quasi madre è la lentezza e tardità di lui, e perciò consequentemente quanto più l'una di queste due uien' soperchiando l'altra nell'udirsi tanto maggiormente è necessario che ui si rappresenti più la

Here Mei is observing a phenomenon also pointed out by Pietro Bembo,²² that words possess qualities of low and high pitch, roughness and smoothness, lightness and heaviness, which permit them to express not only meaning but feeling. Mei concentrates on pitch, which when high expresses excitement and liveliness, when low sleepiness and depression, when intermediate calm and steadfastness. There is a natural relationship between pitch and emotional state, related to the amount of heat in the speaker's soul.

The speed of delivery and the rhythms formed by the acute and grave accents of speech, Mei theorized, have a similar effect on the affections. There is a natural relationship between the soul's heating up and the acceleration of its movements, and these are reflected in the pitch movements of the voice.²³

Intense heat induces quickness and rapidity, and excessive cold tardiness and slowness, while the temperate always carries with it moderation and tranquility. Therefore when souls that are stirred become heated, we can hear this from the quality of the voice, which, owing to the quickness of movement, reaches for higher pitches and, as it were, the higher modes, whereas when these movements are hindered by fear or similar affection, it goes lower, while in tranquil souls none of these changes appear.²⁴

Some years later, Mei applied his theory more directly to music in a letter to Vincenzo Galilei of 8 May 1572. It is clear, he said, that:

affections are moved in the souls of others by representing, as if before them, whether as objects or recollections, those affections that have been previously aroused by these images. Now this cannot be brought about by the voice except with its qualities of low, high, or intermediate pitch, which nature provided for this effect and which is a proper and natural sign of that [affection] which one wants to arouse in the listener.

uirtù dell'una, che dell'altra; e che la doue le si senton' del pari si apparisca mezzana e temperata disposizione conciosiache ciascuna simiglianza, quasi destando naturalmente passioni simili a se, muoua nell'obietto nato al riceuergli proporzionatamente alla sua uirtù sempre affetti simiglianti."

²² Pietro Bembo, *Prose... della volgar lingua* (Venice: G. Tacuino, 1525).

²³ How this theory of Mei works in Tuscan poetry is explained by Barbara R. Hanning in *Of Poetry and Music's Power: Humanism and the Creation of Opera* (Ann Arbor, Mich.: UMI Research Press, 1980), pp. 32-34.

²⁴ Mei, *Della compositura*, fol. 54v: "Perchè il troppo caldo induce prestezza, e' celerità, e il troppo freddo tardità e lentezza, si come il temperato ha seco sempre mediocrità e' quiete. onde è nella qualità della uoce per la cagion' medesima si sente, che dalli animi commossi, quando son' riscaldati, per la celerità de' mouimenti s'innacutiscono, per dir così, i tuoni di lei, e quando per il timore ò altro effetto tale sono impediti, s'ingrauiscono, dove ne quieti non apparisce niuna di queste alterazioni."

It is likewise very well known that pitches intermediate between the extremely high and the extremely low are appropriate for showing a quiet and moderate disposition of the affections, while the very high are signs of a very excited and uplifted spirit, and the very low of abject and humble thoughts, in the same way that a tempo [*numero*] intermediate between rapid and slow reveals a poised spirit, while a rapid one manifests an excited spirit, and slow tempo a sluggish and lazy one. It is clear that all these qualities both of pitch [*armonia*] and of time [*numero*] have by their natures the capacity to move affections similar to their own.²⁵

Galilei popularized Mei's ideas in his *Dialogo della musica antica et della moderna* of 1581, pointing out that the natures of high, intermediate, and low pitch and of fast and slow motion were different, and to mix them up simultaneously as was done in polyphony cancelled out their power to move the affections.²⁶ Echoing Mei, Galilei complained that the music of his own day had no other goal than to please the hearing, whereas the ancient aimed "to lead someone by its means into the same affection as one's own."²⁷

A younger admirer and associate of Mei in the Florentine Accademia degli Alterati and Accademia Fiorentina, Lorenzo Giacomini de' Tebalducci Malespini (1552-1598), pursued the psycho-physiological theory of musical expression to a deeper level in two academic discourses of 1586-1587 that were later published. The Alterati had devoted one of their sessions—on 28 February 1572—to the question, "whether the movement of the affections is outside the art of rhetoric," and the next five sessions to the passions in oratory. The subject of the affections even reached the Florentine stage in 1574 with a carnival masque entitled *Gli affetti*.²⁸ The Alterati returned to the topic in March 1584, when Giacomini argued that poetry was better at moving the passions, rhetoric at persuading.

Giacomini treated the affections in music as well as in poetry and drama in a discourse of 1586, "De la purgatione de la tragedia,"²⁹ a lengthy commentary on a cryptic passage in Aristotle's *Poetics* whose meaning was much debated at this time. In defining tragedy, Aristotle had written:

²⁵ Mei, Letter to Vincenzo Galilei, 8 May 1572, trans. in Claude Palisca, *The Florentine Camerata: Documentary Studies and Translations* (New Haven: Yale University Press, 1989), p. 58. Italian text in Claude Palisca, *Girolamo Mei: Letters to Vincenzo Galilei and Giovanni Bardi* (2nd. ed., Stuttgart: Hänssler-Verlag, 1977), p. 92.

²⁶ Vincenzo Galilei, *Dialogo della musica antica et della moderna* (Florence: G. Marescotti, 1581), p. 81.

²⁷ *Ibid.*, p. 89: "per essere non altro il fine di questa [d'hoggi] che il diletto dell'vbito, & di quella [antica] il condurre altrui per quel mezzo nella medesima affettione di se stesso."

²⁸ Claude Palisca, "The Alterati of Florence, Pioneers in the Theory of Dramatic Music," in *New Looks at Italian Opera: Essays in Honor of Donald J. Grout* (Ithaca, NY: Cornell University Press, 1968), p. 23, reprinted with a prefatory note in Claude Palisca, *Studies in the History of Italian Music and Music Theory*, p. 419.

²⁹ Giacomini, *Orationi e discorsi* (Florence: Sermartelli, 1597), pp. 29-52.

“Tragedy is an imitation of an action... through pity and fear affecting the proper catharsis, or purgation of these emotions.”³⁰ Some thought that he meant that an affection such as fear could be purged by representing the opposite, driving out the fear by representing a courageous deed. Giacomini argued that Aristotle wanted to compare the effect of tragedy to cathartic medications that are homeopathic, such as rhubarb, aloe, and black hellebore, which were administered to purge humors that were similar in nature to the cure: the choleric, phlegmatic, and melancholic respectively.³¹ So a tragedy represents fear to drive out fear and wrath to rid us of anger.

Of the ancient musical modes, the Phrygian and Mixolydian, and of the instruments the aulos best effected purgation, because they actively moved the affections, while the Dorian tended rather to calm the listener.³² Music in the first two modes contracted the soul and relieved it of the spirits that rise to the seat of the fantasy in the anterior part of the brain when a person is excited or saddened. The contraction explains the cries of lamentation,

expelled by Nature through a natural instinct to remove the bad disposition that afflicts the sensitive part of the soul, contracting it and weighting it down, and especially the heart, which, full of spirits and heat, suffers most. Therefore the heart moves to shake off its pain and expand and liberate itself of anguish. The lungs and other organs of the voice are set in motion and emit shrieks and groans if not impeded by the intellect. In this way the soul weighted down by sorrow lightens itself and gives birth to sad conceits and liberates the passionateness that was in it. Having delivered itself of these, the soul remains free and unburdened. So, even if it wants to cry some more, it cannot, because the vapors that filled the head and are the substance of tears have been consumed. They remain scarce until the mind returns to its earlier disposition because of some internal alteration of the vapors, or through some active qualities, sad imaginings, or an external incident.³³

³⁰ *Politics* 6.2.1449b.

³¹ Here Giacomini refers the reader to Galen and to Alexander Aphrodisias' commentary in his Problem 58.

³² Giacomini was apparently a musical amateur and had a command of Greek. He left in manuscript a respectable translation of the pseudo-Aristotelian *Problems*, section XIX, on music. His amanuensis was Giorgio Bartoli, who copied, perhaps for Giacomini, the only existing exemplar of Mei's letters to Vincenzo Galilei and Giovanni Bardi in Vatican City, Bibl. apostolica vaticana, MS Regina lat. 2021.

³³ Quoted from Giacomini, *Orationi*, pp. 39-40, and trans. in Palisca, *Studies*, p. 421: “Da la medesima cagione derivano le voci lamentevoli per naturale instinto senza nostro accorgimento da la Natura procacciate; per rimuovere cioè la mala dispositione, che affligge restringendo & aggravando la parte sensitiva, e ‘l cuore principalmente, che come pieno di spiriti, e di calore, piu patisce, onde per scuotere il dolore, e per allargarsi, e liberarsi dal affanno, si muoue, e muouesi il polmone, e gli altri organi de la voce, e fansi strida, e gemiti, se dal intelletto non sono impediti. Per queste vie l'anima gravida di mestizia si sgrava, e partorisce i dolorosi concetti, e gli appassionamenti, che erano in lei, i quali partoriti, resta libera, e scarica, si che quando il bramasse, piu non potrebbe piagnere,

These changes in the soul may be brought about not only by real-life experiences but by imitations of them presented to the eyes and ears: "happy or painful objects reaching the soul through the sight or hearing alter or move it in such a manner that the soul, surprised and almost enchanted by the delight of the imitation and other delights that poetry contains, not stopping to contemplate the reality of the thing, feels internally those affections that it is accustomed to feel for real things."³⁴ But the author must feel the emotion deeply to be able to embody it in the imitation. "True affection makes us find and express images capable of moving others' souls through the force of sympathy. Focused imagination places the poet in an affection and results in his operating not in make-believe and coldly but almost from the heart."³⁵

Giacomini defends the passions against those who like Plato and Cicero considered them turbid disorders. True, the passions when excessive and unrestrained disturb the mind, madly and wildly sweeping us like poorly reined steeds into danger.

But who would call perturbations love, hate, desire, hope, joy? Are not love of country, of a friend, hate for vice, desire for wisdom, hope for happiness, and joy in its possession true virtues or movements that are most useful to virtue? Let us not call them perturbations but affections and spiritual movements (to use Dante's word) and operations of the soul which, after it has known an object, wants it and clasps it to itself, or does not want it and abhors it.³⁶

Science in the 17th century established a foundation for modern physics, planetary astronomy, mechanics, and acoustics, among other fields. But understanding of the psychology and physiology of the affections did not advance much beyond the theories inherited from the past. What was original in Descartes' *Passions de l'âme* (1649), apart from his adaptation of traditional theory to the newly discovered circulation of the blood, was

essendo consumati quei vapori materia del pianto, che riempievano il capo, fino a che o per altra interna alterazione di vapori, o da qualità attive, o per trista imaginatione o per accidente esterno non ritorna a la primiera disposizione."

³⁴ Giacomini, "Del furor poetico," *Orationi*, p. 63: "gli oggetti lieti o dolorosi per mezzo de la vista o del udito arrivando al anima, in tal maniera l'alterano, e commuovono, che soprapresa e quasi incantata dal diletto del imitatione, e da gli altri dilette; che seco porta la poesia, non curando discorrere intorno a la verità de le cose, in se sente quelli affetti, che sentir suole per le cose vere."

³⁵ *Ibid.*, p. 67: "il vero affetto fa trovare & esprimere concetti atti a commovere per la virtù de la sympathia gli animi altrui, così la fissa imaginazione costituirà il poeta in affetto, e farà che operi non fingendo e con freddezza ma quasi di cuore."

³⁶ "De la purgatione," *Orationi*, p. 43: "chi dirà perturbatione l'amore, l'odio, il desio, la speranza, l'allegrezza; se l'amore de la patria o del amico, l'odio del vizio, il desiderio de la sapienza, la speranza de la felicità, l'allegrezza del possedimento di essa son vere virtù o movimenti giovevolissimi a la virtù? non gli dicemo dunque perturbationi, ma affetti, e spirituali movimenti (per usare la parola di Dante) & operazioni del anima, in quanto dopo haver conosciuto l'oggetto, lo vuole, e si piega ad esso, o non vuole, e l'abborrisce."

more fanciful and dialectical than a result of new observations, experiments, or interpretation of the facts. He abandoned the tripartite division of the soul and the traditional physiology of the four elements, humors, and temperaments while retaining the animal spirits. Athanasius Kircher, by contrast, based the hundred or so pages dedicated to the passions in music in his *Musurgia universalis* (1650) on the familiar doctrine of the divided soul, the humors, temperaments, and spirits.

Although Descartes, residing in Holland since 1629, had probably completed his *Passions de l'âme* there by 1646, it was not published until late 1649 in Amsterdam and Paris. Kircher, who wrote his book in Rome and finished it in 1647,³⁷ did not have an opportunity to study Descartes on the passions and is not known to have corresponded with him. The two authors conceived their works independently, though they had in common not only a deep engagement with the passions but the conviction that moving the affections was a primary goal for music. Descartes began his *Musicae compendium* (1618) with the words "Renatus Cartesius' Compendium of music, whose object is sound, whose end is to delight and move in us various affections..."³⁸ Kircher went beyond this to declare the goal of all music is to move the affections.³⁹ Descartes and Mersenne were fellow students, though some years apart, at the College de la Flèche and remained in touch throughout their careers. Mersenne probably knew that Descartes was writing or planning to write on the passions but does not reveal any knowledge of Descartes' theories. Mersenne exchanged infrequent letters with Kircher, who based some of his treatment of the mechanics of string instruments on Mersenne's writings. Kircher in Rome, Mersenne in Paris, and Descartes in Holland—distant from each other geographically as well as philosophically, each went his separate way in studying the affections.

Kircher, with his unlimited curiosity, asked some fundamental questions. What characteristics in music are responsible for moving the affections? How do these relate to observable changes in the body of the performer and listener? What affections is music capable of moving and by what means? By what process is an affection communicated through the hearing to human feeling? What different affections do diverse genres of music move? Is it possible to define a musical vocabulary of the passions? Why do people respond differently to the same music?

³⁷ Letter to Giovanni Battista Doni in A. M. Bandini, *Commentariorum*, p. 214. See Ulf Scharlau, *Athanasius Kircher (1601-1680) als Musikschriststeller* (Marburg: Görlich & Weiershäuser, 1969), p. 40.

³⁸ René Descartes, *Musicae compendium* (Utrecht: Gisbertus à Zijl & Theodorus ab Ackersdijck, 1650), p. 5: "Compendium musicae Renati Cartesii huius objectum est sonus finis ut delectet, variosque in nobis moveat affectus..."

³⁹ *Musurgia universalis*, Book 7, Part 2, chapter 1, p. 565.

Kircher begins his treatment of the affections with a summary of traditional humoral theory.⁴⁰ The vapors from the four humors are mixed in various proportions according to the objects of the imagination. If the object is full of indignation or jealousy, the spirits and the vapors from the gall bladder, mobilized by the imaginative force, acquire the temperament, of warmth and dryness and drive the soul into affections of anger, fury, and rage. If the object is agreeable and full of love, sanguinous vapors from the liver become warm and humid, and, agitated by soft and harmonious movements, sweetly and tenderly move the soul to taste joy, hope, confidence, love, and cheer. If the object is terrifying, sad, and tragic, the vapors rising from the receptacle of black bile endow the animal spirit with a cold and dry temperament, subjecting the soul to melancholy, sorrow, pain, lamentation, and similar affections. A delicate, smooth, and moderate object, neither sad nor joyous, causes the vapors to become cold and humid, and the animal spirits impel the soul to passions of cheerfulness, calm, confidence, and noble love.

Kircher's explanation of how music can initiate this process or flow from it depends on his essentially Pythagorean and neo-Platonic conception of a common architecture of harmonic numbers shared by the soul and music.⁴¹ Consonance pleases because its ratios agree with the innate harmonic structure of the soul. If the sounding motion of the air is proportionate it affects the hearing and soul felicitously, if disproportionate, unfavorably. Both the outer and inner air are in constant motion, the outer depending on the sound, the inner on the individual temperament. Particular temperaments are receptive to certain frequencies, but the outer air's tremors can alter the motions of the inner air.

The active harmonic agent for Kircher is the ascending or descending melodic interval. An interval affects the soul differently if it is small or large, and this is particularly true of the tone and semitones and their location within a scale. The sound-bearing exterior air stirs the air within the ear and communicates to the animal spirit the proportions of the exterior sounds.

Height and lowness of pitch, tension and relaxation, rapidity and slowness, softness and hardness by their proportion and temperament, alter the spirit, and this in turn alters the soul. When sound is high pitched (tense), the spirit will be

⁴⁰ Athanasius Kircher, *Musurgia universalis sive Ars magna consoni et dissoni* (Rome: Typographia haeredum Francisci Corbelletti, 1650), Book 7, Erothema (Problem) 7, pp. 551-552.

⁴¹ This is detailed in *ibid.*, Vol. 1, Book 7, Part 2, chapter 1, pp. 564-568, "De musurgia patheticae... ratione," and Vol. 2, Part 1, chapter 2, "De natura et productione consoni et dissoni."

similar to fire and *cholera*, if low pitched (relaxed), it will resemble an earthy humor, if intermediate, it will cause moderate affections.⁴²

...
Granted that a musical tone is a movement that communicates to the air a motion exactly proportionate, that the air is in a continuum with the animal spirit, which itself is in perpetual motion, it follows that at the same time as the soul (in which harmony is innate and congenital, as stated in our musical metaphysics) is excited by song and the fantasy by the object represented by the words, the air excites a natural humor altogether equivalent and proportional to the object and to the sonorous movements. As to the vapor, it then rises and mixes with the animal spirit—already excited by the sonorous numbers of the song and the air—that is continuous with it. Finally through its agitation the spirit impels the soul to affections proportionate to the numbers and to the words. In fact, in all things there are hidden proportions, the concurrence of which are necessary to all exterior activities, as in the marvelous accord or disaccord that the Greeks called sympathy and antipathy. These are most apparent in musical art.

Therefore the sonorous number, as it sets the interior air in motion, impresses on it harmonic movements, then animates the imagination. The latter, in turn communicates these impulses to the humors, and the humors, mixed with the vaporous spirit—the interior air—finally move the person to what they convey. It is in this manner and none other that music moves the passions.⁴³

Marin Mersenne was more interested in the physical properties of musical sounds than in music's effect on the passions, a subject he approached with circumspection. He recognized that animals use their voices to express what they feel, tending toward high pitch in sadness and anger, low when they are melancholy. In humans, pitch indicates mostly the size of the vocal organs; the quality of the voice is a surer sign of the affection.

⁴² Ibid., Book 7, Part 2, chapter 1, p. 566: "Acumen itaque & grauitas, intensio & remissio, celeritas & tarditas sonori motus, quas mollities & durities consequuntur, qua proportione & temperamento spiritum alterant, hoc eodem & animam alterabunt. qui si intensior & acutior, acutiores & igni seu cholerae similes; si remissior, remissiores & terreo humori similes; si medium tenuerit, medias affectiones efficit."

⁴³ Ibid., Book 7, Erothema 7, p. 552: "Nam cum sonus harmonicus motus quidam fit aerem ea prorsus proportione qua ipse constat, incitans; aer autem spiritui animali, qui in perpetuò similiter motu est, continuus sit, fit vt simul, ac anima (cui harmonia naturaliter, vt in metaphysica nostra musica dicitur, insita est eidemque congenita) harmonia, phantasia verò obiecto, quod verba praesentant, fuerit concitata, aer concitet naturalem humorem obiecto, & harmonicis motibus prorsus similem, & proportionatum, vapor verò inde eleuatus spiritui animali iam ad harmoniae, aerisque continui harmonici numero concitato commistus; animam tandem agitatione sua ad affectus numeris, & verbis proportionatus compellet: latent enim in singulis rebus proportionem quaedam, quarum concursu omnes rerum exoticae operationes perficiuntur, vtique in admirabili rerum consensu dissensuque; quam sympathiam, & antipathiam Graeci vocant, ita maximè in harmonico negotio elucescunt. Numerus igitur harmonicus primò aerem cùm intrinsecum concitat, eique harmonicis motus imprimit; deinde phantasiam impellit, haec impulsa humores concitat, humores vaporosi spiritui siue aeri intrinseco misti, tandem hominem ad id inclināt, quod referunt, atque hoc pacto harmonia, non alio passiones mouet."

The bilious speak quickly and brusquely, while the melancholic speak slowly, and the sanguine at a moderate pace.⁴⁴ Mersenne was more interested in how song could express the affections through what he called “accentual music” (*la musique accentuelle*). This is accomplished through “the art of the harmonic orator, who must know all the steps, rhythms, movements, and accents suited to excite listeners to any desired feeling.”⁴⁵ In speech meaning is conveyed through words, passion through accent and inflection.

Nature itself teaches us which accents we must use to show and signify our passions and our affections. We express these in simple speech or song only through artifice, for singing and speaking depend on art and instruction, but we weep, cry out, and give certain accents to the voice and words without having learned to do it.⁴⁶

Each passion and affection has its own accents. For the sake of brevity Mersenne reduces the passions to three: anger, joy and sorrow. In angry speech, for example, the voice may rise a whole tone, third, fourth, or fifth and leans on the last syllables of a word, while in a sad affection it often descends a semitones.⁴⁷ Rhythmics applied in the practice of drums, trumpets, dances, ballets, songs, and poems give delight to listeners and spectators and excite them to various passions.⁴⁸

Descartes at the outset boasts of being the first to treat the passions and consequently felt compelled to start afresh, because the little the ancients wrote about them was incredible.⁴⁹ Descartes may have staked out too broad a claim, and his own credibility was vulnerable. This was not an area of study in which he could apply mathematics and geometry, through which he reached truthful accounts in the physical sciences. We may forgive him for ignoring Bartholomaeus Anglicus. He evidently had read

⁴⁴ Marin Mersenne, *Harmonie Universelle*, Livre premier de la voix, Prop. 7, 2:8-10.

⁴⁵ Ibid., Livre sixiesme de l’art de bien chanter, Part 3, De la musique accentuelle, 3:365: “l’Art de l’Orateur Harmonique, qui doit connoistre tous les degrez, les temps, les mouuemens, & les accents propres pour exciter ses auditeurs à tout ce qu’il veut...” For other analogies Mersenne makes to oratory, see David Allen Duncan, “Persuading the Affections: Rhetorical Theory and Mersenne’s Advice to Harmonic Orators,” in *French Musical Thought, 1600-1800*, ed. Georgia Cowart (Ann Arbor, Mich.: UMI Research Press, 1989).

⁴⁶ Ibid., Prop. 11, 3:366: “... la nature mesme nous enseigne de quels accents il faut vser pour monstrier & pour signifier nos passions & nos affections qui sont seulement exprimées par artifice avec la simple parole, ou avec le chant, car le chant & le discours dépendent de l’Art & de l’instruction: mais nous pleurons, nous crions, & donnons certains accents à la voix & aux paroles, sans auoir appris à les faire.”

⁴⁷ Ibid., prop. 16, 3:373.

⁴⁸ Ibid., prop. 17, p. 374.

⁴⁹ *Passions*, Part 1, Article 1.

some of the writings of Vives,⁵⁰ but his notorious aversion to the theories of others would have discouraged any close consultation. A highly original product of pure meditation and introspection, the treatise on the passions is an important, systematic, insightful analysis of the subject.

Descartes highlighted some distinctions that were only implied in previous treatises. As opposed to the Aristotelians, he emphasized that the body, not the soul is the source of life, since the soul remains after death (Art. 6). The passions exist in the body as movements of “a certain very thin air or wind called animal spirits” that travel in the nerves, tiny tubelike filaments, conveying the impressions of the senses and controlling the body’s muscular movements (Art. 7). As opposed to these bodily functions, the soul, though capable also of voluntary actions, experiences passively the movements of the spirits as affections or perceptions (Art. 27). The soul has little control over the actions and representations that cause the passions, which persist as long as their cause remains present. The will cannot stop them but only resist some of their effects, such as denying an urge to violence aroused by hate (Art. 46).

Descartes proposed the novel theory that the denser components of the blood flow speedily everywhere else, but only the thin animal spirits can enter the brain’s minute pores, through which they reach the nerves (Art. 10). In another fanciful departure, Descartes identified the pineal gland, an unpaired organ in the middle of the brain, as the communication center to which all the nerves lead and from which the animal spirits are distributed to the appropriate parts of the body (Art. 35). The one reference to an artistic application, which points indirectly to music, is the idea that we can take pleasure in feeling moved by passions—even sadness and hate—when we see them represented in the theater, because then they do not threaten our bodies while barely tickling the soul (Arts. 94, 147, 187).

Despite all the theorizing by Mersenne, Descartes, Bernard Lamy,⁵¹ and others, the passions remained foreign to French music in the 17th century. Mersenne missed in French music the accent of the passions that he heard in the Italian:

They [the Italians] observe many things in their recitatives that are missing in ours because they represent as much as they can the passions and affections of the soul and of the mind, for example, anger, fury, scorn, rage, fainting of the heart, and many others, with a violence so strange that one would think that they were touched by the same affections as they represent in singing. Our French singers in-

⁵⁰ See Noreña, *Vives*, pp. 161, 167-168. *De anima et vita libri tres* was published in Bruges in 1538 and among the reprints was that of 1563 in Utrecht.

⁵¹ Bernard Lamy, *L’art de bien parler* (Paris, 1670). See William G. Waite, “Bernard Lamy, Rhetorician of the Passions,” in *Studies in Eighteenth Century Music: A Tribute to Karl Geiringer*, ed. H. C. Robbins (New York: Oxford University Press, 1970), pp. 388-396.

stead content themselves with pleasing the ear, using a perpetual sweetness in their songs that deprive them of vigor.⁵²

The vogue of the passions swept England in the late 16th and early 17th century. Bright (1586),⁵³ Wright (1601),⁵⁴ Fenner (1641),⁵⁵ and Hobbes (1650)⁵⁶ among others published treatises dedicated to them. For Roger North in 1728 moving the affections while delighting the sense of hearing was still a goal of music: "Musick hath 2 ends, first to pleas the sence, & that is done by the pure Dulcor of Harmony, which is found chiefly in ye elder musick, of w^{ch} much hath bin sayd, & more is to come, & secondly to move ye affections or excite passion."⁵⁷

The Italians, though they theorized less about the passions than the French or English, intuitively found the means to move them through music. Most of the musical examples that Kircher presents in score to illustrate the affections are by Italians of previous generations such as Palestrina and Gesualdo, or by composers in his Roman circle, as Johann Hieronymus Kapsberger (ca. 1580-1651), Antonio Maria Abbatini (ca. 1609-ca.1677), Giovanni Troiani, Gino Angelo Capponi (ca. 1607-1688), and Giacomo Carissimi (1605-1674).⁵⁸

Preoccupation with the passions peaked in Germany, where the ubiquity of the affections in every artistic domain in the mid-17th century is strikingly illustrated by Lohenstein's play *Agrippina*, first published in

⁵² *Harmonie Universelle*, Livre sixiesme de l'art de bien chanter, Part 2, De l'art d'embellir la voix, les recits, les airs, ov les chants, Prop. 6, 3:356: "Quant aux Italiens, ils obseruent plusieurs choses dans leurs recits, dont les nostres sont priuez, parce qu'ils representent tant qu'ils peuuent les passions & les affections de l'ame & de l'esprit, par exemple, la cholere, la fureur, le dépit, la rage, les defaillances de coeur, & plusieurs autres passions, avec vne violence si estrange que l'on iugeroit quasi qu'ils sont touchez des mesmes affections qu'ils representent en chantant; au lieu que nos François se contentent de flatter l'oreille, & qu'ils vsent d'une douceur perpetuelle dans leurs chants; ce qui en empesche l'energie."

⁵³ Timothie Bright, *A Treatise of Melancholy... with Diuerse Philosophicall Discourses Touching Actions and Affections of Soule, Spirit and Body* (London: John Windet, 1586).

⁵⁴ Thomas Wright, *The Passions of the Minde* (London: V. S. or W. B., 1601).

⁵⁵ William Fenner, *A Treatise of the Affections, or, The Soules Pulse* (London: Printed by E. G. for I. Rothwell, 1641).

⁵⁶ Thomas Hobbes, *Humane Nature, or, The Fundamental Elementsof Policie: Being a Discoverie of the Faculties, Acts, and Passions of the Soul of Man, from their Original Causes* (London: T. Newcomb for Fra: Bowman of Oxon, 1650).

⁵⁷ Roger North, *Musical Grammarian* (ca. 1728), ed. Hilda Andrews (London: Oxford University Press, 1925), pp. 14-15. I am indebted to Paul Lang, *Music In Western Civilization* (New York: W. W. Norton, 1941), p. 436, for pointing out this interesting passage in the version of North's essay published by Andrews from British Library MS Add. 32533.

⁵⁸ Kircher, *Musurgia*, Vol. 1, Part 2, chapters 3-6, pp. 586-620. Kircher tended to choose music by composers he knew in Rome or whose music was available there.

Breslau in 1665, in which one critic has found mentioned 110 different terms for affections.⁵⁹ The title page of the choral-instrumental collection *Theatrum affectuum humanorum* (4th ed., Munich, 1717) shows ten figures representing *odium* (hate), *desperatio* (desperation), *tristitia* (sorrow), *timor* (fear), *puca* (*pudor*? shame), *ira* (anger), *gaudium* (joy), *spes* (hope), *audacia* (courage), and *amor* (love). In the middle stands *virtus in medio* (virtue in the middle), proclaiming the moral that we should seek moderation, a happy medium among the competing affections.



12. Title page of Franz Lang's *Theatrum affectuum humanorum* (1717)

⁵⁹ Reinhart Meyer-Kalkus, *Wollust und Grausamkeit: Affektenlehre und Affektdarstellung in Lohensteins Dramatik am Beispiel von 'Agrippina'* (Göttingen: Vandenhoeck & Reprecht, 1986).

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