Athanasius Kircher, Musurgia Universalis (Rome, 1650) : the section on musical instruments

Frederick Baron Crane
University of Iowa

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Athanasius Kircher,

Musurgia Universalis (Rome, 1650):
The Section on Musical Instruments

translated and edited by

Frederick Baron Crane

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts, in the Department of Music in the Graduate College of the State University of Iowa

August, 1956

Chairman: Professor Albert T. Luper

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The task of translating the section on musical instruments from *Musurgia universalis* was undertaken in the hope that it would provide a useful addition to the readily available original sources on the history of instruments. It should be pointed out, however, that its usefulness is limited by several factors: the relatively large amount of speculation and insignificant material, the author's extensive borrowing from other writers on the subject, and his general lack of reliability. It must be stressed that Kircher must be read with great caution, and his statements compared, when possible, with other sources. I have pointed out many inaccuracies, but it was not possible to call attention to every doubtful passage.

A few words about the tables of contents, plates, figures, tables, and musical examples might best be inserted in this place. The tables have been provided with the page numbers of the original publication as well as of this translation. The order of the numbers of sections and musical examples is quite irregular in some parts of the original. In general, these have been left as they were; in Chapter I of Part II several section numbers have been revised or supplied; such numbers have been placed in
brackets. In addition, the section and paragraph headings are quite inconsistent; in making out the table of contents, an attempt was made, as far as possible, to place subheadings of equal weight in line with each other. Marginal notes have been included in the table of contents whenever they function as titles. A number of the titles of figures in plates and of tables, and nearly all the titles of text figures do not actually appear in the text, and have been supplied in accordance with their contents.

I wish to express my especial indebtedness to Professor Albert T. Luper for his careful check of the translation, his helpful advice and suggestions.

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INTRODUCTION

Athanasius Kircher

The author of Musurgia universalis was born on May 2, 1602 (or 1601; reference works disagree on the year, as on several of the dates of Kircher's life) at Geisa, a small town in the district of Fulda, in central Germany. He studied liberal arts in the Jesuit college at Fulda, and on October 2, 1618, entered the Society of Jesus at Paderborn. On the dissolution of the Jesuit house at Paderborn, Kircher, who had completed his novitiate, visited the houses of his order at Münster and Cologne, where he studied philosophy, the natural sciences, and classical languages. He taught these subjects for a time at the Jesuit colleges at Koblenz and Heiligenstadt. In 1625 he began his theological studies at Mainz and in 1628 was ordained priest. In 1630, after residing in Speyer, where he finished his probation, he was given a professorship at the University of Würzburg, where he taught ethics, mathematics, natural sciences, Syrian, and

1. The best readily available biographies are those by E. G. in the Nouvelle biographie générale, Vol. 27, Cols. 769-776, and by Adolf Muller in The Catholic Encyclopedia, Vol. VIII, pp. 661-662. The present account is largely adapted from these. The chief primary source is Kircher's autobiography, which appears in Fasciculus epistolarum . . . Athanasii Kircheri, edited by Ambros Langenmantel, Augsburg, 1684. xvi
The following year Kircher made a hasty departure from Würzburg ahead of the Swedish armies under Gustavus Adolphus, quitting Germany for good, and staying first in Lyons, then in Avignon. During his stay in Speyer, Kircher had become interested in the study of Egyptian hieroglyphics, and contact with the French scholar Nicolas Peiresc (1580-1637) while in Avignon made this his chief study for the duration of his stay there. In 1637 (1635?) he received an appointment to the chair of mathematics at the University of Vienna. On the recommendation of Peiresc, Cardinal Barberini led the Pope to intercede with the Emperor to let Kircher be called to Rome instead, to edit and publish the Coptic-Arabic glossary in the possession of Pietro della Valle, considered indispensable to the deciphering of the hieroglyphics. Cardinal Barberini secured for him a position at the Collegium Romanum to teach mathematics, physics, and Oriental languages. In 1643 he was released from his teaching duties to devote himself entirely to research. Rome remained his residence until his death there on November 28 (or October 30), 1680.

It would be out of place here to present more than a short summary of Kircher's extremely wide-ranging activities. His extraordinary thirst for knowing the
unknown, combined with a shaky grasp of scientific method, led him to many obvious errors and false conclusions, but at the same time made him a pioneer whose work in a number of fields is worthy of respect and attention.

On a number of trips about Italy and the Mediterranean Kircher gathered first-hand information on the subterranean forces involved in earthquakes and volcanic activity. His works on the subject, especially *Mundus subterraneus* (Amsterdam, 1665), were important contributions to the explanation of volcanic phenomena. In the study of Egyptian hieroglyphics, also, Kircher was a particularly notable pioneer, although here, as in all of his studies, much that is utterly fantastic is combined with the plausible. His other contributions lie in the diverse fields of philology (his studies embraced Italian, German, Spanish, French, Portuguese, Latin, Greek, Hebrew, Chaldaic, Syrian, Samaritan, Arabic, Armenian, Coptic, Persian, Ethiopian, and Chinese; he also invented a universal written language), medicine, physics, mathematics, astronomy, oceanography, cryptography, music, history, and anthropology. He published 37 works during his lifetime, many of them bulky folios of two or three volumes. He is credited with a number of inventions; those of importance include the magic lantern, the Aeolian harp, and one of the earliest counting-machines;
Kircher's Writings on Music

Kircher as Musician

In the second Preface to *Musurgia universalis,* Kircher feels compelled to explain why he considers himself qualified to write on music:

I hear, among other things, that this objection is made to me: "How can the author have the audacity, since he is not a musician by profession, to undertake to correct and emend masters in the art, brought up in it almost from the cradle, and what is uppermost, to place himself as master over them, with more audacity than modesty?" To these I answer that I am certainly not and have never been a musician by profession, since it is a calling not appropriate to my religion; nevertheless people will not condemn me as

2. Rome, 1650, unnumbered page xxi, at the beginning of Volume I.
unmusical for not having passed on the elements of music to boys as a schoolmaster, for not having acted as a public choir director in churches, for not having shown myself mercenary in composing for the sake of a little money. It is clear that such disparagers are not familiar with the rules of logic, in that they do not know that this is the worst inference, one ridiculous in its logic. "He does not make the art his profession, therefore he does not know it" (by profession I always mean the way anyone makes a living). The Prince of Venosa was not a musician by profession; did he therefore not know the art? The famous kings Ptolemy and Alfonso were not musicians and astronomers by profession; did they therefore not know the art? This is the very worst inference, as I have said, of ignorant musicians, for I am referring only to these, and by no means to musicians who are wise appraisers of matters. Therefore, although I have never been a musician by profession as explained above, yet it is known that from an early age I have devoted my attention not only to more distinguished arts and sciences, but also to the practice of music, with the most thorough study and steadfast labor; and let them have no doubt that I have not been concerned with musical speculation only, since various compositions of mine printed in Germany, but under the name of others, are passed around to the greatest pleasure of listeners and held in esteem; the specimens published in this book can offer abundant testimony to what I know and don't know. For since it was my purpose to restore music, and I would consider it useless to pursue my intent without the theory of music, I have devoted myself to both, always with the most ardent study, so that the most skilled theoretical contemplation would strengthen the otherwise feeble and infirm bases of practice; unless musicians have joined such contemplation to their practice, they should certainly know that they will labor in vain to advance music.

Aside from his writings on music, Kircher is unknown as a musician; the only evidence of musical activity that has come to my attention is the four-part chorale with
instruments which Eitner\textsuperscript{3} says appears in manuscript part-books in the Brussels Conservatory. So far as is known, no compositions printed "under the names of others" have been attributed to Kircher. Further, it is difficult to establish Kircher's authorship of any of the examples in \textit{Musurgia}; he does not claim that any specific ones are his; many are anonymous and might be assumed to be his. We will see, however, that most of the anonymous examples in the chapter on instruments are borrowed. From the evidence of his writings, on the other hand, we can agree with Kircher that his musical qualifications were satisfactory; a rather superficial examination shows that while his approach to music was more a theoretical than a practical one, his ideas were not unsound artistically. Any personal deficiencies he may have had were prudently remedied by consultation with some of the most eminent musicians in Rome. In the second Preface to \textit{Musurgia}\textsuperscript{4} he lists his collaborators: in the church and motet styles, Antonio Maria Abbatini and Pedro Heredia; in the canon style, Pietro Francesco Valentini and Francesco Picerli; in the instrumental, Hieronymus Kapsberger

\textsuperscript{3} Biographisches-bibliographisches Quellen-Lexikon, Leipzig, Breitkopf und Härtel, 1900-1904, Vol. 5, p. 370.
\textsuperscript{4} Vol. I, p. [xvi].
(probably his chief collaborator, and obviously a personal friend); and in the recitative, Giacomo Carissimi; and others.

**De arte magnetica**

The first work of Kircher's that contains material of particular musical interest is *Magnes sive De arte magnetica opus tripartitum...*, Rome, 1641 (second ed., Cologne, 1643; third ed., Rome, 1654). The contents of Book III, "Musical Magnetism," are as follows: Chapter I, "The magnetic power and faculties of music. The affections of the mind to which music excites, and the diversity of tones. The causes of consonant and dissonant numbers." Chapter II, "Tarantism; the tarantula, its magnetism and amazing sympathy with music. The various gestures of those affected by tarantism. The music and harmony and instruments customarily played for those affected by tarantism." These headings suggest that the musical materials of *De arte magnetica* are essentially reproduced in *Musurgia*.

**Musurgia universalis**

Kircher's chief musical work, one of his major publications, and one of the most important theoretical works 5. As listed by J. G. Walther, Musikalisches Lexicon, Leipzig, Wolfgang Deer, 1732, pp. 340-341.

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on music of the seventeenth century, is the Musurgia, or to give a fuller title,


Later editions are sometimes mentioned with the dates 1652, 1654, 1662 (at Amsterdam), and 1690. Fétis, however, mentions that he has seen more than thirty copies, and all had the date 1650; Eitner lists only this edition. The copy in the State University of Iowa Library is from 1650, as are all those I have found listed in library catalogues. It is possible, however, that a few copies of the original printing were issued with new title pages on the later dates. A German translation by Andreas Hirsch of extracts from Musurgia was printed in Hall (Suabia) in 1662.

Kircher's work was presumably completed before June 16, 1648, the date of the approval of the General of the


Society of Jesus which appears on page [xxiv]. The title might be translated as "The Complete Science of Music"; musurgia is a Latinization of μουσουργία, which in classical Greek means singing or making poetry. Kircher uses the word in the sense art or science of music; a musurgus is a musician, or sometimes a musicologist. Kircher has at least one earlier precedent for the use of the word musurgia in his title, the Musurgia seu praxis musicae of Ottomar Luscinius (Strassburg, 1536).

The Musurgia is a comprehensive presentation of the musical knowledge of Kircher's time. It includes material on music history, acoustics, aesthetics, theory, composition, instrumentation, and the philosophical and magical aspects of music. Kircher is primarily concerned with the theoretical side of the art; every chapter, if not devoted to a theoretical branch, has a theoretical introduction and many interruptions to theorize. He is passionately eager to fathom all that is hidden: for every phenomenon whose cause or nature is not obvious he must search for it; this compulsion very frequently leads him into error, but occasionally results in fresh contributions of value. It would be impossible, without a very extensive study, to define Kircher's contributions to musical scholarship; it seems probable, however, that in the fields of acoustics and xxiv
style classification he made advances of particular importance.

The influence of Musurgia extended over most of Europe for at least a century after its publication. It is reasonable to say that nearly all the important writers on music of this period are familiar with the work. Among those who frequently quote from Kircher or indicate familiarity with the contents of Musurgia are Marcus Meibom, Wolfgang Prinz, Sébastien de Brossard, Jean-Philippe Rameau, Johann Gottfried Walther, Johann Mattheson, and Jakob Adlung. J. S. Bach may have been acquainted with it, although a lack of any documentary evidence hardly justifies Wanda Landowska's statement that he held it in high esteem. It should be mentioned that many writers, e.g., Meibom and Adlung, show more contempt than respect for Kircher.

A good and rather lengthy summary of the contents of Musurgia is available in Hawkins' A General History of the Science and Practice of Music; it is not necessary to repeat this account. The summary below lists in short the contents of each book, with more detailed discussion of material of interest to the modern scholar that is not


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discussed at length by Hawkins. The title and subtitle following the number of each book are translated from those of Kircher.

Book I. "Anatomical. The nature of sound and the voice" (Vol. I, pp. 1-42). The nature, production, and transmission of sound; the anatomy and function of the ear; the anatomy and production of the voice; the production of sounds by animals, birds, and insects. Pages 26-27 contain a curious discussion of the cry of the American sloth, which consists of the notes of the hexachord ascending and descending. "If music was first invented in America, I would say that it must have begun with the amazing voice of this animal."

Book II. "Philological. Artificial sound or music; its first introduction, age, changes, propagation." (pp. 43-79). The invention of music; the nature of music; its divisions; ancient music: Hebrew instruments; famous Hebrew musicians; the Psalms; modern Hebrew music; Greek music: instruments; forms; modern Greek (church) music.

Book III. "Arithmetical. The theory of harmonic intervals" (pp. 80-158). An extensive introduction on mathematics, particularly of proportions; musical intervals and their proportions; scales; tetrachords (largely based on
Greek theory); the genera; the Greek and modern modes.
 Kircher's accounts of ancient music are far from trustworthy, a fact most emphatically pointed out only two years after the publication of Musurgia. Marcus Meibom, in his collection of Greek writers on music, devotes eight pages of the Preface to a vituperative attack on Kircher, whom he accuses of writing without having consulted a single ancient author.

Book IV. "Geometrical. The geometrical division of the monochord" (pp. 159-210). A short introduction on geometrical progressions; location of various intervals and scales on the monochord.

Book V. "Symphonurgic. A new, true, certain, and comprehensible method of composing all types of melodies" (pp. 211-414). Did the ancients have polyphony? (no); plainsong; measured music; counterpoint; a few notes on sixteenth-century styles (pp. 313-315); canons. The book is a thorough treatise on composition in the "ecclesiastical" style (stile antico). The examples are presumably by Kircher (see above, pp. xx-xxi).

Book VI. "Organic music, or, instrumental music" (pp. 415-530). Part I (pp. 416-452) is on strings and their


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properties: introduction on geometry; the acoustical theory of strings; materials, etc. Parts II, III, and IV, dealing with string, wind, and percussion instruments respectively, are the source of the present translation. (For their contents, see the Table of Contents.) A large proportion of the material on instruments is borrowed from Mersenne. The text is frequently paraphrased after Mersenne, with Kircher's own observations and ideas worked in. All of the engraved figures in the plates are copied from the Harmonie universelle, with only two exceptions, the spinettino, Plate V, Figure III, and the organ prospect, Plate X. About half of the woodcuts in the text are copied from Mersenne. Although Kircher seldom acknowledges his source, his frequent references to that author (with whom Kircher was personally acquainted, at least through correspondence) suggest his indebtedness. Surprisingly, it is the Harmonie universelle and not Mersenne's Latin treatise from which Kircher draws his material. That this is true is demonstrated by the fact that Kircher always refers to Mersenne's work as Harmonia universalis, a Latinization of the French title, and that Kircher's Latin terminology is largely his own, differing

widely, although not entirely, from that of the Harmonicorum libri. It is also surprising that Kircher seems not to be acquainted with the work of his compatriot Praetorius; no mention is made of his name, and the content shows no evidence of borrowing.

The importance of Kircher's treatise on instruments is considerably eclipsed by those of Mersenne and Praetorius, both of which are more thorough and original and (particularly that of Praetorius) relate more closely to contemporary practice. Nevertheless, Kircher's contribution, like those of other minor encyclopedic writers on instruments in the seventeenth century (Cerone, Fludd, Zacconi), is an important supplement to these better-known works.

Book VII. "Diacritical. Antiquo-modern musicology, in which the different natures of each are discussed" (pp. 531-690). Part I. Ancient Greek music: its nature, instruments, notation (pages 541-542 present Kircher's famous Pindar Ode, usually listed as one of the few surviving examples of Greek music. Its authenticity, however, has been seriously questioned; the opinion is widely held that it is a forgery of Kircher's, but all evidence is circumstantial, and the question must be regarded as not yet

settled);\textsuperscript{15} was ancient music better than modern? (with a discussion of national styles, pp. 542-545); ancient theory; ancient and modern vocal music, polyphony, instrumental music compared (Kircher finds modern music generally superior, modern instruments much superior); the power of music; how various sounds arouse various affections (especially with relation to ancient music).

Part II. The invention and development of polyphony; plainsong and its abuses; polyphony and its abuses; music and the affections (pp. 564-620; with a great many musical examples by Palestrina, Johann Hieronymus Kapsberger, Gesualdo, Antonio Maria Abbatini, Joannus Trojanus Tudertinus, Giacomo Carissimi, Giuseffo Tricarico, Giovanni Angelo Capponi, Cristóbal Morales, Ioannes Cousu Gallus): introductory; the effects of each church mode; conditions necessary for music to arouse affections; musical styles (pp. 581-597); how to sing to arouse affections; how to compose to arouse affections. The use of dissonances; chromatic and enharmonic composition (composers of chromatic and enharmonic works named are Domenico Mazzocchi and Galeazzo [Sabbatini?]; meter and its notation; royal music

It is for his contribution to the doctrine of the affections and his classification of styles that Kircher is most often mentioned by present-day musicologists. The question of the affections particularly stimulated Kircher; he touches on it again and again, particularly in Books VII-X. Kircher's attempt at a classification of styles is the most comprehensive that had yet appeared. As with the doctrine of the affections, the discussion of styles is widely scattered through the work. Kircher's classification of styles is threefold, according to temperament, nationality, and function. He distinguishes nine styles according to function: church (ecclesiasticus); canon (canonicus); motet (moteticus); fantasy (phantasticus: includes fantasies, ricercatas, toccatas, sonatas); madrigal (madrigalescus); melismatic (melismaticus: ariettas, villanellas, etc.; i.e., light vocal music for recreation); dance (hyporchematicus), with two subdivisions: ballet (theatricus) and social dance (choraicus); instrumental (symphonicus; this style varies with different instruments); recitative (dramaticus or recitativus; the only style in which Kircher employs a thoroughbass).16

16. For discussions of the doctrine of the affections and Baroque style classifications with reference to Kircher, see xxxi
Book VIII. "Miraculous Musicology. A new musarithmetic art recently invented, by which anyone, no matter how unskilled in music, can attain a perfect knowledge of composing in a short time" (Vol. II, pp. 1-199). Part I. Mathematical introduction on permutations; tables of permutations of any 3, 4, 5, 6, and more notes.

Part II. Rhythm; meter.

Part III. Composition by musarithmetic means: consists essentially of tables giving, for four voices, series of figures (1-8, for the notes of the scale) which may be applied to any mode and to different rhythms, and used in different combinations, one set of figures for each line of the text. Tables are presented for each of the Greek meters used in Latin poetry. How to do the same for poems in Hebrew, Chaldaic, Arabic, Samaritan, Ethiopian, Armenian, Greek, Italian, Spanish, French, German, and Illyrian; musical rhetoric: how to vary the simple formulas for rhetorical purposes; composition of canons by musarithmetic means; composition in all styles.

Part IV. How to construct and use diagrams and
mechanical tools for composition.

Book IX. "The magic of Consonance and Dissonance. In which the more recondite aspects of sounds, and the secrets of all the science of music are brought into the light by countless experiments" (pp. 200-363). Part I. The power of music; how harmony, consonance, and dissonance produce their effects; the affections; the nature and effects of the various intervals. On pp. 204 and 212 he describes musical glasses, even pointing out that one can produce different tones by relatively filling or emptying the glass, but does not make the suggestion that the principle be used for musical purposes. Kircher may, however, be the first to mention this phenomenon.

Part II. The miraculous power of music in curing diseases, e.g., melancholy and tarantism (summarized from De arte magnetica), with scientific explanations.

Part III. Portentous sounds: the walls of Jericho, the Pied Piper, bells that ring by themselves to announce disasters (explained as by the action of angels or demons).

Part IV. The magical phenomena of echoes: acoustical explanation; extensive rules for the propagation of echoes (apparently based on an analogy with light); how to set up echoes for various effects; use of tubes to propagate sound; famous echoes; how to construct palaces so that no one
can talk in the slightest whisper without being overheard; all kinds of apparatus for the transmission of sound.

Part V. Automatic musical instruments: how to power and play organs automatically; a bell automaton; the Zymbelstern (Kircher is perhaps the first to describe it in print); the Geigenklavizymbel; designs for all sorts of musical automata (birds, Pan with pipes, Cyclopes with tuned anvils); the Aeolian harp (Kircher is commonly mentioned as the first to apply the principle, known in the ancient world and middle ages, of strings caused to vibrate by the wind, to the construction of a special musical instrument. Strangely, the Aeolian harp remained in obscurity until about 1770, when it became very popular in England, and a little later in Germany).

Book X. "Decachord of Nature. Or organ of ten pipes, by which it is shown that the nature of things relates to musical and harmonic proportions, and moreover that the nature of the universe is nothing other than the most perfect music" (pp. 364-462). God regarded as the organist, the

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17. For an account, see Albert Protz, Mechanische Musikinstrumente, Kassel, Bärenreiter, 1939, pp. 67-75.


19. Ibid., p. 16.
world as the organ; the harmony of the four elements; the music of the spheres; the harmony of minerals, plants, and animals with the heavens; how the laws of harmony govern all that exists; the harmony and rhythm of man and the human body; the harmony of the affections; the music of love; political music; musical metaphysics; the music of angels; the harmony of God with the whole of nature.

**Oedipus aegyptiacus**


**Phonurgia nova**

The last work of Kircher containing material of musical interest is


A second edition from 1683 is sometimes mentioned; as in the case of *Musurgia*, Eitner lists only one edition, and the second may be spurious or the first with a new title page. A German translation by Agathos Carione (pseudonym of Tobias

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20. _Loc. cit._

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Kircher devotes a great many pages of the Preface to testimony that he was the first to invent the speaking-tube, disputing the claim of Sir Samuel Moreland, published in his Tuba stentoro-phonica, London, 1671.

Phonurgia is not essentially a new work, but a reprint of parts of Musurgia, with some additions. Book I (pp. 1-170) is based on Book IX, Part IV, of Musurgia. It also includes, with a few additions, the material on the Aeolian harp from Book IX, Part V. There are a few notes on modern musical instruments, with illustrations: the trumpet (pp. 59-61), serpent (p. 135), the colascione (p. 157), and the mysterious machine of Michele Todini de Sabaudia (pp. 167-170). Book II (pp. 171-229) repeats Parts I-III of Book IX of Musurgia with a very few additions.

The Translation

The present translation was undertaken in the hope that it would provide a welcome and useful supplement to the source material available to the student of the history of musical instruments. The knowledge, gained in preparing the translation, of Kircher's lack of trustworthiness and
originality, has somewhat tempered my anticipation of the value of the project. Nevertheless, I believe that what Kircher does have to offer has made the effort worthwhile.

The most practical realization of my purpose, to make available the information contained in Kircher, seemed to be offered in including in the translation all the part of his work that dealt with instruments as the principal theme. In consequence, a rather large amount of somewhat irrelevant material has been included, such as the discussions of keyboards and methods for determining the proportions of organ pipes, and some relevant material has been omitted. The bits of information about contemporary instruments and practices which are scattered throughout the work (and in Phonurgia as well) have not been included. The more important of these have been mentioned in the synopses of these works on pp. xxvi-xxxi.

Again, realization of my primary purpose has governed the mode of translation. Although it is difficult to decide what objectives actually motivated Kircher, on the surface, at least, it seems that his choice of subject matter and means of expression were made in order to display his erudition rather than actually to inform. In his time Latin was by no means dead as a scholarly language, and indeed, considering his status as a sort of international scholar's
scholar, it is not surprising that his works, without exception, were written in Latin. On the other hand, the vernacular was used almost exclusively by his time for musical treatises; his is perhaps the last major one published in Latin. His style is based on classical Latin, but with frequent concessions to modern constructions. The language is not difficult, except for occasional obscurities which arise mostly from the difficulty of expressing some technical point, or from Kircher's misunderstanding of it.

The goal of presenting Kircher's information in an accessible form has suggested several principles which have been employed in the translation. Whenever it would not do too much violence to Kircher's manner of expressing himself, the terminology used is that which is standard in modern English contexts. Kircher's own terminology is of a varied nature. Frequently he employs a classical Latin word with a modern meaning, e.g., testudo for lute. Many of these usages were standard in the Latin of his day, many apparently his own property. Some Latin words, which Kircher never uses to refer to any but ancient instruments, have been left in the original. Some of his terms (and nearly all of his proper names) are Latinizations of modern words, particularly Italian ones. Occasionally he uses a modern word. Frequently he resorts to coined words, often in Greek or

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Latinized Greek, which describe the instrument, part of an instrument, or abstract concept, e.g., *fistula tristoma* (three-holed flute) for *galoubet*. Often he offers a selection of possible synonyms; these have been translated by a single English term.

Much of the time, Kircher's Latin does not translate literally into smooth English, or is not the smoothest or most grammatical Latin in the first place. In such cases, I have given most weight to clarity of expression, communicating the sense of the original with a different syntactic arrangement. I have not hesitated to alter punctuation radically; it is frequently considerably at variance with modern practice.

There are no footnotes in the original text; all those appearing in this edition are the translator's. Obvious errors, whether the printer's or the author's, I have usually corrected without any notation; where there is some doubt as to the intention, or where the errors are very copious, as in many of the tables, I have made a note on my procedure. The few errata listed in the original publication, mainly referring to musical examples, have been incorporated without special note.

It would be quite cumbersome and superfluous to point out in detail the borrowings from Mersenne. They have
been indicated in a general way in the preceding section; as a rule, I have mentioned them in footnotes only where necessary to clarify Kircher's text, tables, or figures, or to explain extensive changes in them.

A number of changes in format have been dictated by logic and the requirements of the typewritten page. In Part II, Chapter I, the numbering of sections has been revised; some of the numbers are missing in the original; others are out of order. Numbers supplied or changed have been placed in brackets. The tables generally follow Kircher's form and placement on the page, with some changes for the sake of clarity, and some made inevitable by the different format and the limitations of the typewriter. Long paragraphs have been broken up where modern practice would do so.

Where the musical examples have undergone any essential editing, its nature has been noted. In general, the following changes have been made: bar lines have been supplied where missing, or changed to conform with the meter; note values have frequently been halved or quartered; obvious errata have been corrected, and the corrections noted, except for those appearing in the errata list of the publication itself; a few variants from Mersenne have been included; modern clefs and time signatures have been supplied throughout.
THE GREAT ART OF CONSONANCE AND DISSONANCE

BOOK SIX

_INSTRUMENTAL MUSIC_
THE GREAT ART OF CONSONANCE AND DISSONANCE

BOOK SIX

INSTRUMENTAL MUSIC

Preface

All musical instruments are usually divided into three classes; those of the first class are called stringed instruments; they make use of strings and are set in musical vibration by plectra or the fingers, and include the lutes, psalteries, lyres, sambucae, pandoras, barbina, nablia, pectides, harpsichords, and countless others of this class. Those of the second class are the wind instruments, which sound when blown or aroused by the breath, such as pipes, flutes, horns, litui, trumpets, buccineae, and classica. Those of the third class are the percussion instruments, such as drums, systra, cymbals, and bells. Each of these is to be treated in order, so that the origin of the sound in each one may become more clearly understood.

Since the invention of strings was an easy thing, it follows that it was most ancient, and no one must doubt that it occurred in primeval times; for, since nothing is more obvious, and even necessary, than the use of cords for holding together and making various things, and every stretching of any sort of cord gives rise to some pleasing sound, producing various tones according to the tension—
nothing, as I said, was easier for musically inclined men, on being taught by this experience, than finally to invent instruments of every sort. And, in fact, its antiquity is sufficiently established, for the Holy Scriptures teach us (Genesis 4) that the multi-stringed kithara existed before the Deluge. Also the Book of Kings and the Psalms testify that David used a ten-stringed psaltery. But for the construction and properties of ancient musical instruments, see our discussion in Book II of this work.

Even though nothing is better known and more commonplace than the sound of stringed instruments, I dare say that nothing is more unknown than its cause and origin; except for a few, hardly anyone has expounded it rightly. This fact provided me with a powerful stimulus to apply myself with all possible diligence to experiments in sounds, not without huge expenses, in order finally to arrive at a knowledge of these hidden causes. What I accomplished by this continual study and exertion, let the reader fairly judge. But in order that in our Musical Art we might preserve a harmonious order in all, we have divided this book into four parts; in the first of these we have discussed the science of strings, in the second stringed instruments, in the third wind, and in the fourth percussion.
Part II
STRINGED INSTRUMENTS

We can consider in this place the five-fold classification of stringed instruments. The first is that of harpsichords, spinets, and clavichords. All of these are stringed instruments, and are distinguished by a keyboard made up of keys, commonly called a clavier. In the second class are found the instruments which make use of fingerboards.

This sort includes citterns, pandoras, lutes, theorbos, lyres, and viols of all kinds. Some of these make use of the fingers of both hands as plectra, the fingers of the left hand serving to divide the strings according to the laws of music, while the fingers of the right hand serve for the excitation of the strings, as can be seen in the lute, theorbo, and similar instruments. Some also are excited by the quills of feathers, particularly those that make use of metallic strings, such as the citterns and psalteries. There are, in addition, some stringed instruments which are excited by the fingers of both hands, as is done with harps. Some are excited by a bow, whose strings are made of horse

1. Cytharae, which Kircher uses for both citterns and guitars.
2. Plectra is used very loosely; he means to indicate that both hands touch the strings.
hairs and rubbed with rosin; these include viols of all
types. And some are mixtures of two classes, such as hurdy-
gurdies; see the following synopsis for these.

Synopsis of Stringed Instruments

1. Instruments which make use of a keyboard. such as harpsichords
   clavichords spinets

2. Those which make use of fingerboards stretched out in the
   fashion of a long neck, customarily played by means of both hands.
   such as lutes
   theorbos pandoros

3. Those which make use of fingerboards, but are excited by a bow or
   quills.
   such as viols of all sorts
   citterns

4. Those, all of which lack either a keyboard or a fingerboard, and
   are played directly by means of both hands.
   such as harps
   psalteries

5. Those that have some construction which is a mixture of all.
   such as the hurdy-gurdy, which has a keyboard, and uses a wheel in
   place of a bow.

3. Lyra Germanica, from the Italian lira tedesca, so called in the desire to associate this contemptible instrument with foreigners. The Germans, in turn, called it Viola anglaise (Allgemeine musikalische Zeitung, Vol. 2 (1799/1800), Col. 845).
Chapter I

The Structure of Keyboard Instruments

In the first class we have placed those instruments that make use of keyboards. All kinds of harpsichords fall in this class; they are thus called \textit{clavicymbala} because they most commonly represent the musical tones \textit{claves} by means of their keys, for the benefit of tyros, so that they may be aided and guided in the performance of music. Three special aspects of the construction of this sort of keyboard instrument can be considered: first, the arrangement of the keyboard, second, the arrangement and nature of the strings, and third, the variety of tones that they offer. We will discuss all these things in various sections, beginning with the structure, and then taking up the rest of the items in order.

\[I\]

The Construction of Harpsichords

Harpsichords are made in various ways. The most common construction is that which we show in Plate V, Figure I, in which ACBD indicates the form of the whole instrument,

4. The Latin has a subtitle, "Harpsichords". Actually, neither title is quite accurate; almost the entire text is devoted to a discussion of various keyboards.
Plate V. The Harpsichord Family
ACYX the keyboard, ZZ and LL the two rows of tuning pins, around which the strings of brass or steel are turned with a little hammer. After these there follow the two bridges, MN and OP; the two series of strings, supported by these, are held between two series of iron pins. There follows the space of the jacks, QR, fitted with quill plectra; when these are raised by pressure on the keys, the strings are caused to sound. TS and XV are curved bridges, on which the strings are supported; the space between these pairs of bridges increases from a narrow to a broad one according to the length or shortness of the strings; more about this later. This is the most usual construction of the harpsichords used here at Rome. But because it is a decidedly commonplace item, I have refrained from saying more about it; whoever desires more on these matters may go to Mersenne, where he will find everything more fully described. There are those who design the said instruments so that they suggest a harp more nearly than a harpsichord, for the strings take a position not horizontal, but vertical, as appears in Plate V, Figure II. Instruments of this sort are frequently used in Germany, for they are handy, occupying little space, and serving to ornament the chamber; moreover they have a double

5. The clavicytherium. Kircher's (and Mersenne's, from which it is copied) is quite unusual in having the resonator in a horizontal position directly behind the keys, instead of vertical behind the strings.
use, both as harps and as harpsichords.

\textbf{VIII}

\textbf{The Arrangement of the Keyboard, its Very Great Variety, and its Use}

The keyboard or clavier, or, as the Italians call it, \textit{tastatura}, is nothing other than a musical system constructed of keys following the musical scale, in such a manner that the keys, arranged scalewise, produce the desired tone through the excitation of the corresponding strings. As for the excitation, it occurs by means of certain little pieces of wood normally sitting on the heels of the keys, which, from the fact that they jump up, we will call jacks \textit{[subsilia]} from now on; for the same reason they are called \textit{saltarelli} by the Italians, \textit{sautereaux} by the French. These jacks have in the middle a tongue held by a pig bristle, and at the top of this tongue a quill from the feather of a raven or eagle. When the keys push up the little pieces of wood standing on them, \textit{i.e.}, the jacks, the feather quills fixed to the tongue set in motion the strings stretched above them, and so give the tone desired. These tongues are held in place by the pig bristles, of which one end is attached to the jack, the other to the tongue in a truly clever arrangement, so that the quill does not remain above the string after it has set the string in motion, but by the
bending of the bristle by which the tongue is held in place, returns with the lightest motion to a position beneath the string, ready to strike the string with a new jump. So much for the first item, the mechanics of the keyboard; there follows the musical arrangement of the keys.

Musical arrangements truly as various as the variety of harpsichords are observed by various people. Here at Rome a new type of harpsichord has been invented, which they call a *spinettino*, one and a half spans in length, with only eighteen keys; a picture of it appears in Plate V, Figure III.7 The sound of this instrument is so piercing that one who has not seen it can hardly conjecture what kind of instrument it is. It has a very great and truly peculiar power, played in concert with stringed instruments. Some harpsichords contain only three octaves, some three and a half, but the largest and most perfect attain four octaves;

6. Roughly fifteen inches. Possibly this is the length of the keyboard; it is extremely short for the length of the instrument as a whole.

7. Unless Kircher is referring to a new variant of the *spinettino*, he is wrong in saying it is a new invention from Rome; it is mentioned by Praetorius (1619), and examples exist from the early years of the seventeenth century. Kircher's description is inconsistent with the figure, which shows 22 white and 14 black keys. The figure, however, is obviously untrustworthy: the arrangement of black keys is faulty, and only 22 strings are available for a total of 36 keys.
it is the keyboard of such an instrument that Figure I of this plate represents. Now since in the diatonic genus several semitones occur, the manufacturers make use of two kinds of keys, black ones denoting the tones of the chromatic genus, and white ones denoting those of the diatonic genus. But in order that we may make our way gradually, step by step, from the less perfect to the more nearly perfect, it should now be explained by what arrangement the three genera can be represented on the keyboard.

The Imperfect Keyboard, or the Simple Diatonic one In Common Use, Illustrated by Plate V, Figure I

The nature of the three genera of music, the diatonic, chromatic, and enharmonic, has been told fully in the preceding books. Thus nothing remains for us now but to show the arrangements by which we can display these genera on keyboards by the use of many keys, for it is certain that in the diatonically laid-out harpsichord keyboards widely used, as well as in the second type of keyboard,8 many intervals9 necessary to the perfection of the harmony are lacking. This lack can be made up only by increasing the number of keys,

8. See p. 15.
9. Kircher uses the word intervallum rather loosely; sometimes it clearly means interval, but frequently it is closer in sense to pitch or note. Where the meaning is vague or ambiguous, as here, I have retained the original word.
adding new ones to the simple keyboard. Now for the first, common harpsichord and organ keyboards mostly represent one octave by thirteen keys, or what is the same, divide the octave into twelve unequal semitones, according to the following notes:

10. The figures are from Mersenne, as are all the diagrams and figures in Plate VI. The figures are arbitrary ones, representing the length of string which would produce each pitch on a monochord whose total length is divided into 3600 parts. (The F# is corrected from the original, where it reads 2692.) The naturals form a just scale, and the notes corresponding to black keys are all sharps except B♭. Kircher's designations for the various semitones are faulty, and have been emended here, and in the text below, on the basis of Mersenne's list (Cogitata Physico-mathematica, Paris, Antoine Bertier, 1644, p. 347). In order of increasing size, they are minor semitone, 25:24; medium semitone, 135:128; major semitone, 16:15; maximum semitone, 27:25. A useful discussion of the terminology and calculation of these and other intervals of the just system is found in the article "Intervals" by LL. S. Lloyd in Grove's Dictionary, Fifth Edition, London, Macmillan, 1954, Vol. IV, pp. 519-524. The names of the intervals between E and F, A and B♭, and B and C are missing in the original. The clef has been changed
They represent these notes by the thirteen keys of the keyboard, of which eight are white and five black. On the keyboard commonly used they are arranged in the order represented by the four octaves of which the whole keyboard ACYX consists, as Plate V, Figure I clearly shows. Here you see that the first octave of the keyboard, which begins with C sol fa ut (as do all the rest also), contains thirteen keys, eight white ones marked with the letters CDEFGA^C, and five black ones marked with the letters c#, d#, f#, g#, and b#. And thus the whole keyboard is made up of fifty-two keys, arranged in such a manner that each octave may be thought of as divided into twelve unequal semitones. The proportions of these notes are shown by the numbers written under each. Thus the interval between the C key and the C# key is as 3600 to 3456, which is the ratio of the minor semitone; one may reckon in the same manner for the other intervals, and the other octaves. Moreover, on the keyboard of said figure it is most beautifully indicated in what

from soprano to treble. For a discussion of this and the following tuning (p. 15), see J. Murray Barbour, Tuning and Temperament, second ed., East Lansing, 1953, pp. 98-100.

11. b=B#. In the various figures, B orb=Bb; the sharp sign resembles our double sharp: ♯ or ♯. Frequently Kircher uses a sharp where a flat should appear, for example, on the b of the present figure.

12. Kircher's error is obvious: in multiplying thirteen by four, he counts c, c', and c'' twice; the correct figure is forty-nine.
manner organists must arrange the keyboards of the diatonic genus; likewise how, in what proportion and position the keys of the chromatic genus must be inserted between them, and what note and step each one denotes. Since these things are most clear from the figure itself, I have judged it unnecessary to discuss them further. Therefore, in place of further explanation, consult the figure, Keyboard I of Plate VI, which we have exhibited in said plate, together with other keyboards, for the benefit of musicians.

Now the preceding keyboard is not sufficient for all situations, in that many intervals cannot be obtained; since minor as well as major thirds and sixths are not found in many places in which they are necessary. I will demonstrate it in this manner: C is separated from the C#3456 key by a minor semitone, and the latter from the D3200 key by a maximum semitone, which is necessary in order that the interval from C to D may be a major tone. From D to D#3072 is again a minor semitone, and from here to E2660 is a major semitone, followed by a major tone from E to F composed of two major semitones. Consequently F does not have a minor third below, or C one above.\[13\]

---

13. Kircher's reasoning process is rather roundabout, and there are some steps missing. It would be much simpler to say that from D3200 to F2700 is not a just minor third, and the same is true of C3600 to D#3072. Moreover, Kircher is in error in saying that the interval from E to F is composed of
Plate VI. Keyboards
Then the F key is at a distance of only a minor semitone from the F♯2592 key, and this a minor tone from E; therefore D cannot have a major third above. Again, from the F♯2592 key to G2400 there is only a maximum semitone, from which it follows again that E makes a minor third with G, while G makes a just fourth with D and a fifth with C. Then from the G key to the G♯2304 key is a minor semitone, and from this to A a major semitone. From this it follows that from C to A is a major sixth, D to A a fifth, E to A a major third, and F to A a minor third. But C does not have a minor sixth above, nor does D with B♭, which differs from B♭1920 by a medium semitone, and B♭ does not have a minor sixth or third below. From these examples it may be concluded with no difficulty that not all the consonances exist nor can they all be obtained in an octave divided into twelve unequal semitones, that is, one made up of thirteen keys.

**A Keyboard of the Second Type, One Octave of which has Thirteen Keys**

Now if one thought to fill out all the defects of two major semitones; they are in the ratio of 16:15, one major semitone. Kircher's major tone and minor tone are the two values of the tone that appear in the just scale, 9:8 and 10:9 respectively. The former is equal to a minor plus a maximum semitone, the latter to a minor plus a major semitone.

14. Further errors: D to A is smaller than a just fifth by the ratio 80:81, a syntonic comma; E to A is, of course, a just fourth, F to A a just major third.
the preceding keyboard, by replacing the minor semitone from C to C♯3456 with a major one, or what is the same, by enlarging the interval between C and C♯ by an enharmonic diesis, in such a way that C♯15 would stand at the interval of a minor semitone from D, and thus would establish only a minor tone between C and D, while between D and D♯300016 there would be a maximum semitone, he would make a keyboard with thirteen keys in the arrangement indicated by Keyboard II, Plate VI, and would find many consonances that are not found in the preceding one.17 But he should know that this keyboard is also defective, and that there are many consonances in the first one that are not to be found in the second, and vice versa, as is clearly revealed to anyone who compares the figures of one with the figures of the other.

In order, therefore, to design a more complete keyboard, we must join the keys of both keyboards just proposed into one, so that what is lacking in one may be supplied by the other; the result will

15. Actually D♯.
17. The F major scale is now a just one, as a result of the altered D; the black keys all represent flats (not sharps, as in the figure). The figures for "F♯" and "G♯" are in error, and should be 2531 1/4 and 2250. The peculiar placing of the chromatic keys is presented by Mersenne as a possible alternative to the normal one.
be a keyboard with seventeen keys, as illustrated by the third figure in Plate VI.\textsuperscript{18}

\textbf{\textit{J III}}

\textbf{A Keyboard of Nineteen Keys}

But since nothing is wholly blessed, and this keyboard is still found to be defective in many respects, and since in it B has a major third above, while F has a minor and F\# a major third \textit{[below]}, D cannot have a perfect fourth above it.\textsuperscript{19} These intervals, however, are quite necessary to harmonic perfection. Therefore, in order that we may ascend to the peak of perfection step by step, so to speak, we will indicate here another keyboard much more perfect than the third, which is shown in Plate VI.\textsuperscript{20} It has nineteen keys, and is most

\textsuperscript{18.} In combining the two keyboards, the D of Keyboard II has been omitted. The black keys, from left to right, represent C\#, Db, D\#, Eb, F\#, G\#, G\#, Ab, and Bb. Such an arrangement was actually used, although a more common disposition of the keys was that shown in Keyboard V or that in the upper half of Keyboard IV, Plate VI. The previous monochord lengths have been multiplied by four. The figures for D\# and G\# are incorrect and should be 13500 and 9216. (F\# and B\#, which are unclear, are 10368 and 8100.) For a discussion of keyboards with more than the usual number of keys to the octave, see J. Murray Barbour, \textit{op. cit.}, pp. 108-132.

\textsuperscript{19.} This argument is based on a D tuned to 12960, instead of the 12800 of the figure.

\textsuperscript{20.} Keyboard IV. To the last keyboard, it adds the D3240 of Keyboard II, and an A\#2090. The latter bears no simple
useful for the perfection of harmony, and the tuning of organs.

Also, this keyboard contains the three genera of [Greek] music.21 The major and minor enharmonic dieses22 are found from C to the third key Db, which makes a minor diesis with the second key C#, just as the latter23 makes a major diesis with the third key D, and these two dieses taken together make one major semitone.24 Then the major third harmonic relation to any other note on the keyboard; its string length was probably established as an arithmetic mean. Values in error or not easily legible should be: C3600, Db3375, F#2592, G#2304. An F#2560 has been substituted for Gb, to supply a pure major third above D3200. The new value for Eb is an arithmetic mean between E and D3240.

21. Kircher's argument to follow is based on the procedure of fitting the Greek tetrachords into just tuning, a not altogether unjustified approach, as the Greek theorists themselves were in considerable disagreement as to possible tunings for the various tetrachords; the pure major thirds which characterize the just tuning were not unknown (see J. Murray Barbour, op. cit., pp. 15-24).

22. The ratios 25:24 and 128:125. Diesis is used here to denote the quarter-tone (approximate) which is the smallest interval in the enharmonic tetrachord.

23. It is actually Db that makes a major diesis (as Kircher calls it) with D (3240), which is not the third, but the fourth key. The discussion is quite confused from this point on. Kircher, for a professor of mathematics, is excessively careless.

24. It is not at all clear where Kircher is trying to establish his enharmonic tetrachord, whether on the keys C-C#-Db-F, or C#-Db-D3240-F#. Either is satisfactory. Many such tetrachords can be established on this keyboard, wherever the intervals quarter tone-quarter tone-major third can be established upward from any key.
which is required to complete the enharmonic tetrachord occupies the space from the key marked D3240, which is separated from the D marked with the number 3300 by only a [syntonic] comma, to the ninth key F. 25

Then the keys of the chromatic genus are easily found on this keyboard: from the first key, C, to the third is found a major semitone, and a minor one from the latter to the fourth key [D3240]; the minor third which completes the chromatic tetrachord is found from the fifth 26 to the ninth key, i.e., from D to F.

Finally, the keys of the diatonic genus are clearly revealed in this keyboard. From C to the first D [3240] is a minor tone; from this D to E is a major tone, so that the major semitone from E to F completes the diatonic fourth. 27 Furthermore, if you transpose this keyboard up a fourth or down a fifth, there will appear another keyboard, shown in Figure V of Plate VI, whose first key begins with F. 28

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25. Obviously only a minor third. See notes 23 and 24, p. 18.
26. Actually the fourth, D3240.
27. A proper Greek diatonic tetrachord would be F-E♭-D♭-C.
28. The numbers on Keyboard V represent relative vibration ratios, not string lengths, i.e., they are in inverse proportion (with a few exceptions) to the values of Keyboard IV. Values in error are those for G♭, D♭, and E♭, which should be 3375, 4608, and 5184 respectively. The two chromatic keys at the extreme right are superfluous, duplicating the F♯ and G♭ of an octave lower.
Now we will take up another diatonic-chromatic-enharmonic keyboard, one octave of which has twenty-seven keys. It is shown in Plate VI, Figure VI. Whatever lies hidden in music can be revealed by it. On it, not only diatonic, but also chromatic and enharmonic melodies can be demonstrated perfectly, and boys can be accustomed to singing them.

But since this keyboard lacks five commas necessary to absolutely complete perfection, it was necessary to design another keyboard, one octave of which is made up of thirty-two keys. It is so perfect and absolute for displaying any genus of music whatsoever, that nothing can be either taken away from it or added to it. It is seen in Figure VII [of Plate VI], and is laid out with such ingenuity that wherever one begins, one can always build a complete harmonic cycle. The larger Roman numerals written on each key indicate the order of keys on the keyboard. But the preceding keyboard, although lacking a few commas, is much easier and more

29. It is not clear what Kircher means by this. Perhaps he is referring to the circle of fifths; see pp. 35-38.

30. This keyboard is discussed in J. Murray Barbour, op. cit., pp. 108-110.
suitable for playing than this last keyboard, and for this reason I am led to discuss it more fully than the others. For better clarification, we will show the whole system here by means of a table in which we will indicate precisely the intervals of each key with notes, their letter names, and values.\footnote{A number of errors in each column have been corrected. The flats and sharps in column 2 do not appear in the original. The clef has been changed from soprano (but with the clef mistakenly on the second line) to treble. The intervals in column 3 have been corrected on the basis of Mersenne's table of intervals (see note 10, p. 11). The monochord lengths in column 4 are corrected on the basis of the woodcut of the keyboard with twenty-seven keys to the octave which appears in Mersenne, \textit{op. cit.}, p. 345.}
Table Showing the Location, Order, and Proportion of each Key of the Sixth Keyboard Proposed

<table>
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<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>minor semitone</td>
<td>72000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C#</td>
<td>enharmonic diesis</td>
<td>69120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Db</td>
<td>minor semitone</td>
<td>67500</td>
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<tr>
<td>D</td>
<td>major comma</td>
<td>64800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>minor semitone</td>
<td>64000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D#</td>
<td>minor comma</td>
<td>61440</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eb</td>
<td>major comma</td>
<td>60750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eb</td>
<td>minor semitone</td>
<td>60000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>minor semitone</td>
<td>57600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E#</td>
<td>enharmonic diesis</td>
<td>55296</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>minor semitone</td>
<td>54000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F#</td>
<td>major comma</td>
<td>51840</td>
<td></td>
<td></td>
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<tr>
<td>F#</td>
<td>minor comma</td>
<td>51200</td>
<td></td>
<td></td>
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<td>major comma</td>
<td>50625</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gb</td>
<td>subminimum semitone</td>
<td>50000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>major comma</td>
<td>48600</td>
<td></td>
<td></td>
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<tr>
<td>G</td>
<td>minor semitone</td>
<td>48000</td>
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<td>G#</td>
<td>enharmonic diesis</td>
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<td>minor semitone</td>
<td>45000</td>
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<td></td>
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<td>major comma</td>
<td>43200</td>
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<td></td>
</tr>
<tr>
<td>Bb</td>
<td>major comma</td>
<td>40000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>minor semitone</td>
<td>38400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B#</td>
<td>minor semitone</td>
<td>36864</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>enharmonic diesis</td>
<td>36000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This four-fold table illustrates one octave of a keyboard consisting of twenty-seven keys. The first column shows the notes that each key on the keyboard represents, according to the three genera of music, the diatonic, chromatic, and enharmonic; in it a whole note shows the diatonic genus, a half note the chromatic, and a quarter note the enharmonic.\textsuperscript{32} The second column gives the names of the notes corresponding to each key. The third names the intervals between the notes; the fourth shows the ratios of one note to another. This table will serve craftsmen especially well for constructing diatonic-chromatic-enharmonic keyboards.

Furthermore, although Mersenne presents another keyboard much fuller than this (to be specific, one consisting of thirty-two keys), and other fuller ones could be constructed \textit{ad infinitum}, we have judged this one the most suitable of all for incorporating any of the smallest intervals that can be distinguished by the human ear. Various models have been constructed already after this pattern, in Sicily and Italy, especially at Rome. Some of these, in order to avoid the confusion of so many keys, have

\textsuperscript{32} Actually, a chromatic or enharmonic tetrachord may be established on any of the twelve notes of the chromatic scale. But the functions of the various notes of Kircher's table will vary from tetrachord to tetrachord, and not remain fixed, as his key suggests.
placed three keyboards in one harpsichord; the first of these shows the arrangement of the first keyboard [in Plate VI], the second that of the third, and the third that of the fourth, as will become clear a little later.

Having thus completed the subject of the musical keyboard, there remains nothing in the fundamentals of harpsichords as well as of organs but to show in what manner so many strings can be tuned skilfully according to the proportions of the intervals.33

[SV]

A Triharmonic Keyboard, Designed in Accordance with the Ideas of the Ancients, Taken from Doni

Giovanni Battista Doni, a noted musician of our time, proposes this keyboard in his little work on the genera and the modes.34 He describes it as having a triple keyboard, lying one above another, arranged according to the three principal genera of the ancients. Each one of them has two rows; the first row embodies the diatonic tones, the other the flat or chromatic ones, or the enharmonic and metabolic ones. Moreover, they have five classes of keys, each one of which he paints with various colors in this

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33. The tuning procedure does not appear until p. 35. Perhaps what follows was inserted as an afterthought.

34. Compendio del trattato de' generi, e de' modi della musica, Rome, Fel, 1635. See J. Murray Barbour, op. cit., p. III.
manner: he calls the first, of a deep yellow color, the Dorian keyboard, and adapts it to the production of hesychastic music; the second, red in color, he calls the Phrygian, and assigns to it the species of diastaltic music; the third, suited to producing systaltic music, he calls Lydian, and paints a white color. Then he established the flat, enharmonic, and metabolic chromatics, differing in both color and shape according to the effect that each has in
arousing the affections of the mind. 35 But in order that this thing may be more thoroughly understood we have included a picture of the keyboard itself.

The purpose of this triharmonic keyboard is to show the system of the mutation of tones, and the greatest variety of new 36 harmonies arranged according to the three genera. There exists in the home of the Most Illustrious Knight Pietro della Valle 37 a harpsichord of this type, executed with the greatest ingenuity; we have drawn and seen fit to present here only one octave of it. Whoever, with proper consideration, would like to know more about this instrument should read the little work of the author cited, on the genera and modes, Chapters 10, 11, and 12, where he brings in various things on the construction, tuning, and nature of this instrument.

35. Hesychastic, diastaltic, and systaltic are the names given by Aristides Quintilianus and Cleonides to denote melodies that respectively pacify, exalt, and depress the spirit. Flat, chromatic, and enharmonic seem to have about their ordinary meaning here, while metabolic possibly applies to the note D, which has two different pitches, as in Keyboard IV, Plate VI. It is impossible to gain any clear idea of the nature of the keyboard from Kircher's account.

36. Nonarum, apparently a misprint for novarum.

37. 1586-1652, Roman traveller and adventurer.
The Panharmonic Keyboard of Nicolo Vicentino

Nicolo Vicentino, in order to restore enharmonic music, constructed an archicembalo\textsuperscript{38} made up of six keyboards. He asserts that he will produce all imaginable harmonies on them. I have found that Doni later contracted these keyboards into three, and I have found that it is precisely one and the same with the keyboard of Vicentino. For this reason, I have judged it quite needless to add the keyboard of Vicentino here. Whoever desires to know more about its arrangement should consult that author.\textsuperscript{39}

This instrument is made up of six rows of keys, or six keyboards. The first row, painted black, is diatonic and natural, because the keys are arranged tonally. The second row is called chromatic, because, where before the tones were natural, here there are placed only the tones altered by accidentals, as the experienced say. Yet in its own way, it can still be called natural, if a beginning is made somewhere

\textsuperscript{38} Or arcicembalo.

\textsuperscript{39} L'antica musica ridotta alla moderna prattica, con la dichiaratione, et con gli esempi de i tre generi, con le loro spetie. Et con l'inventione di uno nuovo stromento, nel quale si contiene tutta la perfetta musica, con molti segreti musicali. Rome, A Barre, 1555. A short discussion which somewhat helps to clarify the meaningless explanation below is given in J. Murray Barbour, \textit{op. cit.}, pp. 117-119.
in the series of semitones, and then this procedure is continued to the end; then it is called chromatic natural. The third row is called that of chromatic tones transmutted from the natural diatonic series; in it there is a varying arrangement of whole tones, and major and minor thirds. The fourth row is called enharmonic natural if it happens to proceed by dieses; but if it proceeds by semitones you will have the enharmonic mixed with the chromatic. The fifth row is called that of chromatic semitones and tones in a chromatic enharmonic order. The sixth row, finally, is called that of perfect fifths, and hardly differs from the diatonic. But consult Vicentino, who devotes a whole book to these matters. Certainly, whoever will scrutinize most thoroughly these six rows in comparison with the three rows of the Donian keyboard preceding, will see that Doni has gathered together all this six-fold keyboard of Vicentino as if into a synopsis. He will see also that, by the multiplicity of its keys, the instrument of Vicentino not only gives rise to difficulty and the greatest confusion, but even is made altogether useless by the fact that, without any compensating advantage, it does by means of many what can be done by fewer.
The Keyboard of Galeazzo Sabbatini

The rare musician Galeazzo Sabbatini pursued these matters at length and, venturing anew to apply the laws of arithmetic to the three genera, discovered many more things, of which mention is made in various places in this work. Among other things, he designed a new keyboard containing most accurately whatever can be desired in music, most perfect for displaying all harmonies. But since I deem it most proper that it be considered by musicians, I have seen fit to display just one octave of it here; from this one they may visualize the whole system and arrangement.

But since the numbers could not be written on each key of the keyboard, we will place here separately the proportions of each note, in order that the theory of the keyboard may be revealed more clearly.

40. Although the keyboard is not Kircher's invention, he is the first to discuss it in print. See J. Murray Barbour, *op. cit.*, pp. 110-111. Barbour is mistaken in a number of details. The keyboard actually has thirty-eight notes to the octave (Kircher would say thirty-nine). The notes which Barbour says are missing are actually present, as well as an Abb and a Gbb.

41. Several mistakes have been corrected and omissions supplied with reference to the woodcut that follows. The headings above the various columns have been added for clarity.
The Proportions of the Intervals that the Keys, Placed in Order, have with each other, Expressed in Larger Numbers

<table>
<thead>
<tr>
<th>Name of note</th>
<th>Monochord length</th>
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<td>Standard According to Kircher</td>
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</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>B♭</td>
<td>A♭</td>
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<td>A#</td>
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</tr>
<tr>
<td>C♭</td>
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</tr>
<tr>
<td>B♭</td>
<td>B♭</td>
</tr>
<tr>
<td>B♭♭♭</td>
<td>B♭♭♭</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
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<tr>
<td>E♯</td>
<td>E♯</td>
</tr>
<tr>
<td>G♭♭♭</td>
<td>G♭♭♭</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>G♭♭♭</td>
<td>G♭♭♭</td>
</tr>
<tr>
<td>F♯</td>
<td>F♯</td>
</tr>
<tr>
<td>G♭♭♭</td>
<td>G♭♭♭</td>
</tr>
<tr>
<td>A♭♭♭</td>
<td>A♭♭♭</td>
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<tr>
<td>F♯</td>
<td>F♯</td>
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<tr>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>A♭♭♭</td>
<td>A♭♭♭</td>
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<tr>
<td>G♯</td>
<td>G♯</td>
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<tr>
<td>A♭</td>
<td>A♭</td>
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<tr>
<td>G♯</td>
<td>G♯</td>
</tr>
<tr>
<td>B♭♭♭</td>
<td>B♭♭♭</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>
Diagram of the Keyboard of Galeazzo Sabbatini

42. The markings on the diagram are not entirely consistent. A lower case letter is occasionally used. The Db between D and E should be Eb. The A of the second black key of the row at the far right should be A#. The keys are arranged precisely in the order of the table, i.e., in the order of rising pitch.
Explanation of the Signs of this Keyboard

\( \sharp \) indicates the smallest interval of the diatonic, displayed on the black keys marked \( \natural \).\(^{44}\)

\( m \) indicates the smallest interval of the chromatic; the second row of black keys are of this sort; its proportion is 25:24.\(^{45}\)

\( a \) indicates the smallest enharmonic interval of the diesis; the first row of black keys are of this sort; its proportion is 128:125.\(^{45}\)

\# indicates the proportion 2109375:2097152, and is the difference, the excess, by which the major diesis is larger than two enharmonic dieses, which are indicated by this sign\#; it is larger than \( \natural \).

\( n \) signifies the proportion 393216:390625, and is the difference, or excess, by which two enharmonic dieses are larger than a minor diesis.

\( \natural \) signifies the excess of a minor diesis over an enharmonic diesis, in the proportion 3125:3072, like \#.

43. The intention of the list of signs that follows is not quite clear. Perhaps they were to have been incorporated into the figure of the keyboard in order to show the relationships of the various pitches to each other. Some of the explanations are obscure in meaning, and defy the translator's attempts at interpretation. The intervals referred to are the enharmonic diesis (128:125), the major chromatic diesis (135:128), and the minor diesis (25:24).

44. I.e., keys so marked are at an interval of a major semitone (16:15) above the next lower interval.

45. With relation to the next lower natural.
# signifies a major chromatic diesis, in the ratio 135:128.

Note that ♯ and ♭ can be given naturally in all notes, and are indicated by the roots of the natural numbers. Note also that ♯ is always an accidental sign, and does not have its own numbers, and therefore is called an artificial and accidental sign.

Another Simple Keyboard, of the Arrangement of Keyboard I, Plate VI, which may be Transposed to any Interval by means of Certain Registers.

Not long ago Nicolaus Ramarinus⁴⁶ invented a type of harpsichord which has a simple keyboard, such as is in common use, but variable to any interval, so that one tone can be divided into nine commas, variable by means of the same number of stops. The first step,⁴⁷ which is also commonly called the tonus chorista,⁴⁸ is suitable for Roman music; we will have various things to say about this pitch in various other places. But if either the nature of the voices or the transposition of the melody demands it, it can be lowered or raised to any interval. If, for example, the tonus chorista be raised a minor semitone by pulling the stop

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⁴⁶. Possibly a mathematician, or an instrument maker. I have not been able to find the name in any musical or general reference work.

⁴⁷. I.e., the lowest pitch level, or possibly the standard pitch.

⁴⁸. Probably a translation of German Chorton.
corresponding to the semitone, at once the whole system of the keyboard will have a pitch a semitone higher than the tonus chorista. If you wish to raise it a minor third, the stop to which a minor third corresponds will give the desired tuning to the whole keyboard. The procedure is the same for any other interval, and this single instrument can do the same as nine different instruments, each one of which is pitched a semitone higher than the next in order; an altogether fine invention, since it accommodates itself to a voice at any pitch. And since the tone is divided into nine commas in this instrument, and there are this many strings to each key, and the whole keyboard consists of four octaves, the whole instrument contains 212 strings, as many, of course, as all those contained in nine instruments of four octaves. But since this is a laborious thing, and causes the person adjusting it the greatest weariness, perhaps it would be better if, according to the precepts presented in the preceding sections, each string could be divided by different jacks into the given intervals, and the whole business accomplished by a single abridgment, as is done in the clavichord. But we will leave all these matters to skilled artisans to be put into execution.49

49. The best interpretation of this paragraph seems to be that Kircher has confused two different keyboard systems and
Method of Tuning an Instrument with Seventeen Keys to the Octave

Various methods of tuning an instrument are offered by various authorities; see Mersenne for these. We will give here an infallible one, which we may call harmonic circulation, because after three octaves, in almost any genus, there is a return to the first step from which a beginning was made. We begin this circulation with any key producing a

has run together his description of them. The first one is a transposing keyboard, which would have the same number of keys to the octave and the same appearance as the standard one. The transposition might be accomplished by shifting the whole keyboard left or right, so that each key would control any one of several strings. Another possibility would be that there actually were as many as nine strings to each key, with a set of stops, each of which would bring into play the set of strings for a certain pitch. If there were actually nine strings to each key, however, the total number of strings in a four-octave instrument would be 441; the difficulties of constructing such an instrument would probably be insurmountable. The other keyboard system is one frequently proposed by theorists of the seventeenth to nineteenth centuries, with 53 keys, and 53 equal intervals to the octave. (For the history of the system, see J. Murray Barbour, op. cit., pp. 123-125.) Nine of these small intervals ("commas") are very nearly equal to a major tone, and a four-octave instrument would have 213 strings (counting one for the c\textsuperscript{m}). It seems probable that Kircher, with his usual reliance on intuition, jumped to the conclusion that an instrument with nine commas to the tone, and one which could be transposed to any one of nine pitches, were identical. His final suggestion seems to show a lack of understanding of the difference in the production of tone on a clavichord, which allows the use of one string for more than one pitch, and on a harpsichord, which does not, in any normal manner of construction.
fairly low tone, such as F, and ascend and descend always by a fifth and a fourth respectively, until we arrive at the tone corresponding to the first, i.e., the unison, which is first reached at the interval of three or four octaves, i.e., when we have passed through three octaves. From here we can return to the unison by the same steps, descending by fifths and ascending by fourths. Beginning in just the same way with any chromatic or enharmonic step, you will be able to tune them in the same way as the intervals of the diatonic steps, by a spherical revolving, so to speak, as appears in the following diagram.50

Note that although the interval between steps 7 and 8 appears to be a third, it is actually a fourth, and so is

50. In the original, step 2 was unnumbered, and steps 3-14 had the numbers 2-13, apparently a printer's error. Aside from correcting this, no changes have been made. The meaning of the X's is unclear. It is possible that step 8 is supposed to be Ab♭, and the cycle of fifths continued from this point.
the interval at the beginning of steps 13 and 14. Therefore we have expressed these steps on the adjoining staff with chromatic and enharmonic signs, as they lower the pitch a tone.

Therefore, whoever correctly understands this circulation will find no difficulty in tuning any diatonic-chromatic-enharmonic harpsichord, for only in these does this spherical music find its place, because, in running in a circle through all the steps, diatonic as well as chromatic and enharmonic, it finally comes to rest on the first step. But such periodic harmonies are definitely not to be obtained on the harpsichords in common use, since they lack the necessary keys as soon as the fourth step is reached.51

**Corollary**

From the above it is evident that the musician can begin tuning not only from the lowest note, but at any point;

51. Kircher's tuning method shows not only a failure to comprehend the practical approach, but an apparent misunderstanding of the theory involved. While some parts of his commentary are plausible, the whole shows a lack of consistency. Does he mean to have his tuning proceed by pure fourths and fifths? If so, a union with the beginning note will never be reached; the note reached twelve steps later will differ from it by a ditonic comma. Does he mean to indicate a temperament? If the equal temperament, all steps beyond his e⁸ are superfluous; if the meantone, he cannot make use of the enharmonic fourth between his b⁷ and abb (if this is the correct interpretation of the note of step 8). Several more such objections can be raised.
since this cycle passes through all the tones, it must finally arrive at the last note, from which it may be restored to the step from which it evolved.

Thus this musical mystery exemplifies for us that marvelous cyclical element that appears in all things in the universe, which is discussed thoroughly in our *Ars magnetica*,\textsuperscript{52} and more thoroughly in the "Physiologia musica".\textsuperscript{53} But no more needs to be said about the keyboard, and its arrangement and tuning.

The Arrangement and Proportion of Strings in Harpsichords

There is no doubt that the strings of any harpsichord must vary widely in length, if they are to produce a perfect sound, although they could be made all of the same thickness and length, and be perfectly tuned only by increasing and decreasing the tension of each, as has been fully demonstrated in the preceding sections. Yet because long experience has taught that, beside the fact that this procedure is troublesome and difficult, it also produces tones not a bit pleasing, but sounding quite dull and strident. For this reason musicians observe a definite

\textsuperscript{52} See above, p. xxii.

\textsuperscript{53} Book IX, Part I of *Musurgia*. See p. xxxiii.
proportion in the weight as well as in the length of strings. As a result, the sounds that emerge will be brighter, sweeter, and more pleasing to the ear. However, they do not always make each string different in both thickness and length, but sometimes five, six, or even seven are used exactly equal in thickness, but different in length. But if anyone wished to design a harpsichord absolutely perfect in all measurements, I would advise him to use strings differing from each other at least in the proportion of the intervals of the diatonic keys.

Thus, since the harpsichords in common use, the larger ones, mostly have forty-nine keys, twenty-nine white ones, which are called diatonic, and twenty black ones, which are called chromatic, you will easily achieve your aim if you make use of twenty-nine string sizes, in accordance with the number of diatonic strings, all differing in thickness and length. Then the chromatic strings can be equal to the diatonic ones to which they correspond and which they follow at a small interval. But in order to give you more explicit directions in this musical undertaking, I have made up a table to be inserted here, in which everything said up to now is clearly embodied.\[54\]

54. The table is from Mersenne (Harmonie universelle, "Livre troisièmes des instrumens a chordes", p. 121). There are
Table of the Proportion of Strings which Serve for Constructing Harpsichords

<table>
<thead>
<tr>
<th>I Diatonic strings</th>
<th>II Diatonic Ratios of the strings</th>
<th>III Length of the strings</th>
<th>IV Diameter of the strings</th>
<th>V Chromatic strings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>feet</td>
<td>inches</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1</td>
<td>10</td>
<td>0</td>
<td>1/5</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>9</td>
<td>9</td>
<td>2/11</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>8</td>
<td>16</td>
<td>4/25</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
<td>8</td>
<td>15</td>
<td>4/27</td>
</tr>
<tr>
<td>G</td>
<td>5</td>
<td>8</td>
<td>16</td>
<td>2/11</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>10</td>
<td>15</td>
<td>1/10</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>1/12</td>
</tr>
<tr>
<td>C'</td>
<td>8</td>
<td>8</td>
<td>15</td>
<td>2/25</td>
</tr>
<tr>
<td>D'</td>
<td>9</td>
<td>7</td>
<td>9</td>
<td>1/30</td>
</tr>
<tr>
<td>E'</td>
<td>10</td>
<td>6</td>
<td>15</td>
<td>1/37</td>
</tr>
<tr>
<td>F'</td>
<td>11</td>
<td>5</td>
<td>15</td>
<td>1/45</td>
</tr>
<tr>
<td>G'</td>
<td>12</td>
<td>4</td>
<td>15</td>
<td>1/50</td>
</tr>
<tr>
<td>A'</td>
<td>13</td>
<td>3</td>
<td>15</td>
<td>1/61</td>
</tr>
<tr>
<td>B'</td>
<td>14</td>
<td>2</td>
<td>15</td>
<td>1/74</td>
</tr>
<tr>
<td>C''</td>
<td>15</td>
<td>1</td>
<td>15</td>
<td>1/80</td>
</tr>
</tbody>
</table>

Two or three errors in Mersenne's table; Kircher has multiplied these many times, particularly in Columns III and V. The table has been corrected on the basis of Mersenne's. In preparing the table, Mersenne has made a serious and glaring error, which makes the whole table quite worthless. For each octave rise in pitch, he has halved both the string length and the diameter. Halving either one, assuming equal tension, would raise the pitch an octave. Therefore, since tension varies as the square of pitch, if one were to use Mersenne's figures, the tension would have to be divided by four for
Explanation and Use of the Table

(See the figure of a harpsichord illustrated in Plate V.)

This table has six columns:

I contains the notes which correspond to each string and key.

II contains the number of each diatonic string, which must be joined to the corresponding key.

III shows the ratios of the strings to each other.

IV indicates the length of the string.

V exhibits the diameter of each string represented as fractions of the whole.55

VI contains the names of the chromatic strings that correspond to the numbers appearing on the keyboard.

In order to use it, nothing else needs to be demonstrated but how to determine the various strings, both the diatonic and chromatic ones, according to Columns IV and V. If you desire to determine the strings d' and d#, you will find in Column IV that the length corresponding to them each octave rise, and the tension of C would necessarily be 256 times that of c''!

55. Mersenne explains that the fractions represent parts of a line (1/12 of an inch). Kircher has possibly not bothered to read his explanation of the table, and so has explained the fractions (more clearly in the paragraph below) as representing parts of the largest string, although this is clearly false, as the largest string itself is marked 1/5.
is one foot, one inch, and in Column V you will find that the diameter of said string must be $\frac{1}{22}$ that of the heaviest string, i.e., if the diameter of the heaviest and largest string of all be divided into twenty-two equal parts, the strings d' and d#' must have a relative thickness of one twenty-second. Proceed in just the same manner with the rest.

But note that musicians are mostly not concerned with such refinements. In practice they generally determine the thickness of the strings to be used on an instrument from the fifteen sizes of the holes through which they are drawn, which decrease in size in a certain proportion from the largest to the smallest. And actually the wires drawn through them are sufficient for musical purposes. But if someone would make twenty-nine holes whose diameters were the same as the numbers expressed in Column V, it is certain that he could make strings of the greatest perfection, corresponding to each other in the proportion that the present table indicates.

\[\text{[J X]}\]

A Composition Suitable for the Harpsichord

Harpsichords, organs, regals, and all keyboard musical instruments, being most suited to preludes of musical solemnity, and being even the moderators of all musical
ensemble, also require compositions of a sort different from all other instruments, which must be such that with them the organist can not only show his ability, but also prepare and arouse the minds of the listeners with them as preambles, in preparation for the instrumental ensemble to follow. Most people call musical compositions of this sort preludes; the Italians call them toccatas, sonatas, ricercatas. We will include one of this sort here, on ut, re, mi, fa, sol, la, composed by Master Johann Jakob Froberger, Imperial Organist, formerly a pupil of the most celebrated organist Girolamo Frescobaldi. It is adorned with such artfulness, that whether you consider the most perfect manner of composition, and the arrangement of fugues ingeniously chasing themselves, or the distinguished change and variety of time, it will seem that nothing further could be desired. And thus we have chosen to propose it to all organists as a most perfect specimen of this type of composition, that they may imitate it. 56

There follows a specimen of a musical fantasy perfect in all numbers, and most apt for keyboard instruments.

56. The Fantasy is reprinted in the Denkmäler der Tonkunst in Österreich, Vol. IV, Part 1 (Vienna, Artaria, 1897, edited by Guido Adler), pp. 33-37. We have felt obliged to reproduce only the opening bars here, in open score as the work appears in Musurgia. It is interesting to note that this was the only appearance in print of a keyboard work of Froberger's during his lifetime (1616-1667).
Chapter II

_Lutes, Mandoras, and Citterns_\(^{57}\)

The next musical instruments to be described are those that have, in place of a keyboard, a fingerboard with several strings. A fingerboard is the term for the handle of any stringed instrument. Of this type are lutes, mandoras, citterns, viols, and innumerable others of this clan. And although it is hardly proper for a musical scholar to apply himself to them, for they have now become debased in usage.

57. See p. 3, note 1. The chapter also covers bowed stringed instruments and the psaltery.
and are even the common property of laborers of the lowest sort, nevertheless, since we have undertaken to discuss instrumental music, we will include here whatever is appropriate to our designs, discussing their nature and properties, in order that we may not be charged with any omissions in this Musurgia of ours.

Now it should be known that the lute, mandora, and cittern do not differ in essence, but only in the number of strings and the method of tuning them. Lutes and theorbo mostly enjoy full bellies; citterns and mandoras enjoy flat bellies and backs. Lutes and theorbo are mostly fitted with rows of ten, twelve, or fourteen strings; mandoras and the like with at most five or six, of which the first ones are double and the last one, commonly called the cantarella, single. In consequence of the larger quantity of strings with which it is furnished, the lute [Latin testudo, tortoise] also affords a larger variety of consonances than the others. It is so called from the shape of the animal, because it closely imitates it with its bulge curved in the manner of an arch.

The theorbo differs from the lute in that the former has a double pegbox (we call the part in which the pegs wind up the strings the pegbox), the latter a single

58. i.e., the highest-pitched.
one. It is an invention of the moderns, since the ancients make no mention of these instruments. The theorbo gets its name from a certain Neapolitan street musician59 who first doubled the neck of the lute in length and added various strings, since at first it served only for the baritone,⁶⁰ and was in the habit of calling this instrument theorbo as a joke. For theorbo is the name of the instrument with which glovers are accustomed to grind perfumes, and it is a kind of mortar very similar to those little mills with which they are accustomed to dissolve almonds, mustard, and other seeds by pouring on a liquid which combines them into a milk. The first to give particular attention to this instrument was the most famous musician Hieronymus Kapsberger, a German nobleman. He brought it to such perfection that at this time it would seem deserving to snatch the palm away from the rest of the instruments, since no instrument has a greater musical variety, and indeed it is the only one suited to display the diatonic-chromatic-enharmonic system.⁶¹

59. Circumforaneus, probably used here to indicate a musician who played in market-places for hand-outs.

60. Which might indicate that the strings added extended the range upward; the meaning of the clause, however, is obscure.

61. The statement suggests that the theorbo was the only fretted instrument capable of producing quarter tones. By suitably placing the frets, of course, any instrument of the lute family could reproduce the Greek scales.
The Order, Location, and Tuning of the Strings to be Fitted to the Lute

The lute and theorbo do not make use of metal strings, but of strings made of the intestines of animals. The relative length of the strings on a lute is the same, for all are equal in length but different in thickness. Also, all are double except the last, which, as I have said, is called the cantarella, and is single. The makers achieve the relative thickness of each by the number of intestines of which they are made. Here at Rome they make the heaviest lute string of nine intestines, the next of eight, and so on to the last and smallest, which consists of one intestine. But if some artisan wished to proceed more subtly in this business, he could extract the proportions of the diameter of one to the next from the table of harpsichord strings that we presented above, Column V. But these matters should be entrusted to the use, habits, and experience of the manufacturers, who should not be involved more than is proper in attention to subtleties.

Tuning means the musical tightening of strings, and is done according to the musical notes written by the diagram. Let the fingerboard ABDE of the lute or theorbo in Figure I of Plate VII be fitted with ten double strings and one single one, i.e., twenty-one strings in all. You will
Plate VII. Plucked Stringed Instruments
tune this series of strings according to the notes placed on the nut DE of the fingerboard, or according to the intervals of the musical notes which the staff DEGH represents. Thus, the first string stands a minor tone from the second, the second a major tone from the third, the third a major semitone from the fourth, the fourth a major tone from the fifth, the fifth a minor tone from the sixth, the sixth to the seventh a fourth, the seventh to the eighth another fourth, the eighth to the ninth a major third, the ninth to the tenth a fourth, and finally the tenth to the eleventh another fourth. We have shown all these intervals by letters and numbers placed below the notes DE, t indicating a minor tone, T a major tone, S a major semitone, 4 a fourth, and 3 a third. Thus you see the method of tuning the lute in its utmost brevity. All that remains is for us to pass on also the division of the fingerboard in a few words.

\( J II \)

The Division of the Fingerboard of the Stringed Instruments

Our practical musicians are accustomed to proceed

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62. From the numbering and spacing of the frets, AB is clearly meant to represent the nut.

63. The tuning is from Mersenne, where it is clear that the F, C, and G clefs represent pitches an octave lower than usual, i.e., F, c, and g.
thus in the division of the fingerboard: First they divide the whole fingerboard into nine unequal, proportionally decreasing spaces, and fix each space with a string tied around the neck and drawn very tight. These strings [frets] have the same function on the lute as the keys in the keyboard of harpsichords; they divide the octave into various diatonic-chromatic-enharmonic steps, as will be seen later.

First Method of Division

First, they [musicians] divide the whole string into eighteen equal parts. From these they take seventeen for the first place where a string is to be tied, or the first division. Then they divide the rest of the string into eighteen equal parts again, and seventeen of these parts give the second fret, or the second division. Third, they divide the whole string from this fret into eighteen parts again, and seventeen of these will give the third fret. They continue thus until they come to the ninth fret. This method is indeed the easiest of all, for it divides the whole length \( AB-DE \) of the fingerboard, as is seen in Figure I, into nine mean semitones, between a major and a minor, and then, from the division of these, other smaller intervals can be gotten with the least trouble.
Second Method of Division

The second method of Mersenne is a little more exact, for it divides the length of the whole string into 100,000 parts, then takes 94,444 for the first fret, 89,198 for the second, and so on with the others, to the ninth and twelfth, as shown by the numbers written below. This method is based on the method of Aristoxenus, who divides the whole octave into twelve semitones. This procedure for dividing agrees as much as possible with the division of the lute fingerboard. Since we spoke at length of these things in Book IV, I have seen fit to illustrate here only the list of figures of division, together with the musical notes for better understanding.66

64. This method of placing the frets resulted in a close approximation to equal temperament, and was first described by Vincenzo Galilei in his Dialogo della musica antica e della moderna (Florence, 1581).

65. Corrected from 89,298.

66. The string lengths are those that will result from the application of the method described in the paragraph above. The pitches become progressively flatter with respect to those of equal temperament, until the octave is about ten cents flat. The table is quite worthless—if one is to place his frets by means of such accurate decimal divisions, he might much better use a more satisfactory scale, whether just, equally tempered, or meantone. Several of Kircher's values are incorrect, and have been corrected. The whole and half notes signify respectively diatonic and chromatic scale steps.
Third Method

It was shown in the preceding paragraphs that the keyboard of nineteen keys is more perfect than others. They [musicians] establish this also as the most perfect division of the fingerboard of the lute, in order to make possible melodies in all genera. For they cleverly insert here the intervals that were lacking in the former one, according to the following scheme. If you wish to divide the neck of the lute according to it, do so.

(The sign X shows the enharmonic steps.)

67. Or rather, the sharps; half notes indicate flats, whole notes naturals. The actual number of steps to the octave is sixteen. The first column of figures is for a just tuning similar to that of Keyboard III, Plate VI; the second is based on the 18:17 proportions of the two methods above. There are many mistakes in the notes, in their names, and in both columns of figures. They have all been revised by conjecture or comparison with the figures for the Third Method, except the Db, first D, D#, F#, and second Bb of the second column. I have been unable to find any means by which they were derived. The figure under G# in the first column is actually for Ab.
With the string divided into 10,000 parts, for the first fret take 9444 in the lower series of numbers. Then for the second fret take 9222. Proceed in the same manner with the others to the last fret, and you will have the fingerboard of the lute divided with as much perfection as anyone could desire in music.

But since this method is too laborious to be applied by practical musicians, we will impart another method here that depends on the division of the monochord described in various ways in the preceding book, and is the one that follows in Plate VII.

Fourth Method of Dividing the Strings

68. The scale that results from Kircher's procedure is a just one like that of Keyboard III, Plate VI. If the whole string sounded c, the frets would give the following pitches: g, d♭; c or p, d; o, e♭; n, e; m, f; l, g♭; k, g; l, a♭; h, a; g, b♭; f, b; and e, c. Inexplicably, Kircher has given two procedures for finding some of the frets; steps 3 and 4
1. Divide the whole string AC in half at e, as Plate VII, Figure IX shows, and you will have the octave which sounds with respect to AC, the whole string.

2. Divide the string AC into three equal parts. One of these laid off towards the bridge gives the fret k.

3. Divide the string AC into four equal parts. One of these, towards the bridge, gives a fret which makes a fourth with the whole string [i.e., fret m].

4. Divide eA into two parts, and the midpoint will give the desired fret m.

5. Divide the string AC into five equal parts. One of these will give the fret n, which makes a major third against the whole string. Then if three parts of the five are laid off from C, the fret h will be obtained, which makes a major sixth with the whole string, and this is the last fret.

6. If you divide the line AC into six equal parts, one sixth, A to o, will give you the third fret, which makes a minor third with the whole string.

7. If you divide AC into eight equal parts, and lay off three parts, this point i will give you the eighth fret, which makes a minor sixth with AC, the whole string.

locate fret m; steps 8 and 9 locate fret c; steps 7 and 12 locate fret i.
Seven frets will now be had, that give the seven tones consonant with the octave, that is, e, k, m, n, h, o, and i. We will find the minor dissonant intervals as follows:

8. Divide AC into nine or ten equal parts. If one tenth is laid off, the second fret [c] will make a minor tone with AC. If one ninth is laid off, it will give the fret p, which will make a major tone.

9. Divide the space nA into two parts, and now the whole string will be divided into tenths, and c will be the fret of a minor tone.

10. An eighth of the string divided in two will give two sixteenths. The first of these laid off will mark the fret q.

11. Divide Cq again into four parts, and the last will give l, the sixth fret.

12. Divide Cq again into three parts. This will give, at the last point i, the location of the eighth fret, with which qC makes a fifth, while it makes a fourth with l. There remain, therefore, two frets, g and f, the tenth and eleventh, to be found. You will find the former if you divide oC into three parts, for a third laid off will give g, the fret sought. You will find the latter if you divide nC into three parts, for a third laid off will
give the point for the eleventh fret. You see, therefore, with what ease, and at the same time pleasure, the fingerboard of lutes can be divided. Yet the whole system of this division depends on what we amply demonstrated in the fourth book on the various divisions of the monochord.

The cittern follows, which differs from the lute only in that the former enjoys metal strings, and a smaller number of them. For the German and the French cittern, as well as the Spanish [guitar], does not exceed six courses of strings. The Italian is mostly fitted with six courses of strings. Also the cittern is not played directly by the hand, like the lute, but with a feather quill grasped between the thumb and index finger.

Figures V and VI of Plate VII illustrate the tuning of both. The designs of the rest of the citterns together with their tunings are shown by Figures IV, V, VI, VII, and VIII of said plate, q.v. 69

Tuning of the ultramontane cittern  Tuning of the Italian cittern

69. Figures VII and VIII, the mandora and colascione, have characteristics more in common with the lute family.
Also the fingerboard of the cittern is divided differently from that of the lute, for mostly nine frets are applied to the lute, but sometimes seventeen to the Italian cittern. But since this is an uncertain matter, and since each nation uses those divisions that seem to agree more with its own customs, I have thought it unnecessary to linger longer on these matters. Whoever desires better and more exact information, I would urge him to consult the makers of these instruments. For there are almost limitless varieties of citterns: German, French, Italian, English, Spanish, Turkish, Persian, and African. To include all of them would be the material not of this, but of another work. For this reason, we will leave them and pass on to the viols. But so that no reader will be able to complain that this is lacking in the work, we have seen fit to show the various types of citterns together with their tunings in Plate VII.

Finally, it remains for us to insert in this place a sample composition suitable for lutes, theorboes, and similar instruments. It is by the noted cittern player and true Orpheus of the City of Rome, Master Lelio Colista, a youth admirable in habits, talent, and liveliness. But we will include here two compositions, completed with singular industry according to all the rules of this style, so that cittern players may have something to imitate.
70. The actual number of movements is eight. The numbering is inconsistent: Example III is followed by another Example II, and the numbering continued to VI. The movements fall into two groups; the first three, for four unspecified parts, and the last five, for various plucked instruments, decreasing in number from six to two. It is impossible to determine just which are the compositions of Colista (or Calista; outside of the few words of Kircher, nothing is known of his life; a number of instrumental compositions exist in manuscript). A number of styles are evident. Example I resembles lute music least of any of the movements. It is consistently imitative, and would seem to be more appropriate to an ensemble of viols, or might possibly be a transcription of a vocal piece. The second and third examples, when scored on two staves, strongly suggest performance of all parts on a single instrument: the style is in broken chords; usually no more than two notes are struck simultaneously. The fourth through seventh examples share a generally chordal style and long note values; the fourth, fifth, and seventh are related through the use of the dotted rhythms on repeated notes. The last five examples again seem to suggest performance on a single lute (although the six-voice example might require some modification for ease of playing).

Editorial notes: The music is printed in open score (not tablature, which was the conventional way of notating lute and cittern music), and has been condensed to two staves, except for the six-part example, which occupies three staves. A number of mistakes in the first Examples II and III have been corrected; the original note or sign appears in brackets. In the last five examples, note values have been halved, bar-lines have been added, and several editorial sharps added above or below the staff, whenever it seemed appropriate.
Example II, in 9/8 Time
Example III, in 12/8 Time
Example II. An Ensemble of Six Parts Suitable for Citterns, Theorbs, Harps, and Lutes

Cantus I. Cittern
Cantus II. Lute
Altus. Lute
Tenor I. Theorbo
Tenor II. Theorbo
Bassus. Harp
Example III. An Ensemble of Five Parts

Cantus. Cittern
Altus. Lute
Tenor I. Theorbo
Tenor II. Theorbo
Bass. Harp

Example IV. An Ensemble of Four Parts

Cantus. Cittern
Altus. Lute
Tenor. Theorbo
Bass. Harp
Example V.  An Ensemble of Three Parts

Cantus. Cittern
Altus. Lute
Bassus. Theorbo

Example VI.  An Ensemble of Two Parts

Cantus. Lute
Tenor. Theorbo
Viols

By viol is understood that instrument that consists of belly and neck or fingerboard, and which is sounded with a plectrum or bow made of horsehair, the left hand grasping the neck, and its fingers pressing the strings directly. But there is such a variety of these instruments, that whoever lists the customs of the various nations, will also list a corresponding variety of viols. For in this so learned age, almost every craftsman invents viols of new designs. Some add strings to strings; some design them in the fashion of lyres, and there is no lack of those, such as the English, who construct them partly with metal strings and partly gut for greater variety. Whoever desires to know exactly the uses of all of them, should read here Père Mersenne, who treats of them with variety and erudition in a whole work.

Also there is the Lyra Barberina and the Panharmonic Viol of Giovanni Battista Doni, a noted musician of this time, which he describes in a particular book.71 There is the Lyra Argolica72 of Cerone. There is the greatest variety of all of these, as well as the most diverse diversity in the tuning of each. But one cannot be ignorant


72. From Argolis, a district of Ancient Greece.
of this who has understood well the various divisions of the monochord presented in the preceding book, as well as in Chapter I of this part, on harpsichords.

But, so that I may pass on in synopsis what other authors pursue thoroughly, I have seen fit to include here pictures of each of the ones most generally used today, together with their tunings, so that we will not seem to have hidden anything from the reader. Also the most excellent Lord, the Count of Somerset, an Englishman, has thought up a new eight-stringed type of viol, which contains all the secrets of music in the most eminent degree, an instrument most worthy of being heard, one which carries away all listeners in wonder.

Explanation of the Figures Contained in Plate VIII

The larger viol which Figure I in Plate VIII shows, is commonly called the violone. It has mostly four strings; its neck AB is a third of its whole length AC. It achieves a great pleasantness in performing the bass. Its tuning is seen in the notes placed beside it.

73. Text: BC.

74. Apparently a bass viola da braccio. The tuning is copied from Mersenne, and is actually for the violin; Mersenne has placed it beside the figure of the bass viol (the f clef represents f'; in the works of Mersenne and Kircher, the f, c', and g' clefs frequently indicate pitches an octave above or below the ordinary ones).
Plate VIII. Bowed Stringed Instruments
The kit, Figure II, so called \textit{finterculus=little boat}; cf. French \textit{pochette en bateau} from its shape like a boat, is a small viol whose tuning is shown by the notes.\footnote{Kircher has been confused again by the tuning that Mersenne printed by the figure of the kit. The clefs stand for F and c; the tuning is actually that of the bass viola da braccio, Bb\textsubscript{1}, F, c, and g. The kit was tuned a fourth, fifth, or octave above the violin.}

Figure III is a six-stringed viol, somewhat longer than the first viol; it shows the greatest variety of harmony. We have set its tuning beside the fingerboard; it contains two fourths, a major third, then two more fourths, as the numbers under the notes indicate. This is the tuning of the French six-stringed viol; the Italians tune it as follows:\footnote{The instrument is the bass viola da gamba. The two tunings are identical; the clefs in the figure are an octave lower than usual.}

<table>
<thead>
<tr>
<th>Order of strings</th>
<th>Proportion</th>
<th>Notes</th>
<th>Names of strings</th>
</tr>
</thead>
<tbody>
<tr>
<td>String I</td>
<td>80</td>
<td>d'</td>
<td>Canto, Cantarella</td>
</tr>
<tr>
<td>String II</td>
<td>108</td>
<td>a</td>
<td>Sotana</td>
</tr>
<tr>
<td>String III</td>
<td>144</td>
<td>e</td>
<td>Mezzana</td>
</tr>
<tr>
<td>String IV</td>
<td>180</td>
<td>c</td>
<td>Tenor</td>
</tr>
<tr>
<td>String V</td>
<td>240</td>
<td>G</td>
<td>Bourdon</td>
</tr>
<tr>
<td>String VI</td>
<td>320</td>
<td>D</td>
<td>Basso</td>
</tr>
</tbody>
</table>

IV is a smaller viol,\footnote{A violin or viola.} a noble instrument, most suited for a variety of melodic diminutions. It has mostly four strings, with which, however, it ascends as far as four
octaves.

V shows a picture of a lira [da gamba]. This has twelve\textsuperscript{78} strings, and is most suitable for harmony, for one string is not played alone, as in others, but several together, so that at various times players produce two, three, four, or five notes with one stroke. It is an instrument exceedingly suited for the affections of sorrow and lamentation, bringing to the ears the most pleasant music with its mournful murmuring, in the manner of the hurdy-gurdy. See its tuning adjoined to the figure.

VI shows a picture of the hurdy-gurdy, which, although it is a common and low-class instrument, and in use everywhere by beggars, is, however, in structure and in the dividing of its strings, of which it has two or four, as marvelous as it is ingenious. It shows every variety of melody. Moreover, it makes use of its tangents and keys; when the strings are touched by pressing on its keys, you can easily produce any tone you wish, by turning wheel S, which rubs the strings and causes them to sound. In a word, it is nothing other than a monochord, or dichord, caused to sound by stopping it at various places with tangents. But I will waste time if I tarry in explaining an instrument most common everywhere; therefore, consult the adjoined illustration.\textsuperscript{79}

\textsuperscript{78} Actually fifteen; the lowest three are double.

\textsuperscript{79} The second figure of the hurdy-gurdy is labeled pars inversa, i.e., bottom view, but actually depicts a top view of a different model. The protective cover has been removed from the top of the first figure.
Figure VII shows an illustration of a marine trumpet. Since it is very well known, I have judged it unnecessary to waste time in describing it, since we devoted almost all of Book IV to a discussion of it. 

We will add an ensemble of viols composed according to all the rules of this style, and with the greatest genius, by the most celebrated musician of the Pontifical Choir, the Reverend Master Gregorio Allegri, in which skill in writing ensemble music is shown so exactly that it seems nothing could be added to it or taken from it.

Example I. An Ensemble for Viols Most Perfect in all Intervals

à 4. Duoi Violini, Alto, Basso di Viola

80. Book IV is on the monochord, and not the marine trumpet. Kircher's name for both is monochordon.

81. This work of Allegri (1582-1652) apparently calls for the modern string quartet, and may be the earliest composition for that combination. The instrumentation is somewhat in doubt, however, particularly as to the fourth part, whose range is c to g', which would require the fourth position with modern cello tuning. The work has been omitted from the translation, since it is available in a number of modern publications. The incipits of the main sections have been included in Appendix A, p. 166. Transcriptions may be found in Frederic Louis Ritter, The History of Music (Boston, Ditson, 1883), pp. 434-442, and J. W. von Wasielewski, Instrumentalsätze vom Ende des XVI. bis Ende des XVII. Jahrhunderts (Bonn, 1874), No. 15. An article by A. Eaglefield Hull, "The Earliest Known String Quartet", in The Musical Quarterly, Vol. 15 (1929), pp. 72-76, includes facsimiles of the first two pages of the quartet from Musurgia, and a transcription of the whole work, on which the following comments may be made: P. IV, notes 1 and 2: the original readings are not incorrect. P. VII: the original inserts the C time signature one bar earlier. P. XI, note 2: the original has the correct e.
The Psaltery

The psaltery, a stringed instrument, if played by a skilled hand, is such that it would seem to bow to no other, whether you consider the variety of its musical proportions or the marked pleasance of its musical sound. The shape, as you see here, is triangular. It has three series of strings. The first series is indicated by the strings included between A and B, and contains three octaves and a major third, as the names of the notes of the first row show. The second

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82. In the figure, three octaves and a semitone. The range of the center series is the same, and of the right-hand series three octaves and a major third (not a fourth).
series of strings is included between C and D, as is clear from the figure. The third series is included between the letters E and F, and contains three octaves and a fourth, as can be seen. But note that each of these three series has separate strings, for just as the instrument consists of three systems, it also consists of a triple series of strings. Since this arrangement can be done in various ways, we will leave it to the ingenious craftsman. And in order that the instrument may be made more sonorous, skilled craftsmen are in the custom of doubling the strings of each system, or tripling or quadrupling them, according to the size of the instrument, so that all the strings belonging to a certain note are tuned in unison. The noted musician Master Giovanni Maria Canario has an instrument of this sort here at Rome with 148 strings. He plays it so skilfully that one cannot express what a remarkable, pleasant, and unusual sound it presents to the ears. Therefore it is most fitting that even the most skilled masters exercise themselves in playing it perfectly. Moreover, since it is sounded by both hands, holding feather quills, there is no slight difficulty connected with carrying out the business in a fine manner. Playing of this sort requires a dexterous and agile hand, in order that, soon after the strings are set in motion by means of the feather quills, the rest of the fingers stop the
vibration of the plucked strings with a light touch in order to avoid a noisy confusion.

Now, in order that the curious musician may have something to practice with, we will present here a specimen of the tablature, as they call it. The three lines refer to the three series of systems, in such a manner that the lowest line corresponds to the third system or series of strings, the second line to the second series of strings, the third line to the third series of strings, or third system. The letters of the alphabet of the third system, which indicate the corresponding notes, are placed on the lowest line; the letters of the alphabet of the second system on the second; finally the letters of the alphabet of the third system should be placed on the upper line; these are the signs of the corresponding notes in each system.

The musical notes indicate the rhythm of the melody that is to be played, but these are noted in the common way.  

83. Kircher's explanation of the tablature is faulty: twice he explains that the lowest line represents the third system of strings, followed in the same sentence by the statement that the highest line represents the third system. It seems likely that the lowest line is intended to indicate the first system, and that is the basis of the transcription that has been attempted below. It is impossible to be sure about the correct octaves, or about accidentals, which are distributed haphazardly in Kircher's figure. Johannes Wolf, in the Handbuch der Notationskunde (Vol. II, Leipzig, Breitkopf und
Part III

WIND INSTRUMENTS

The wind instruments are all those instruments which are sounded by the breath and wind. Indeed, the number of these can be limitless, what with variations in the density, rarity, and striking of air in hollow bodies. Who is not aware of the great variety of flutes constructed in one way or another, the many differences in trumpets, the variety of wind instruments? We will discuss briefly the constructions of all of these.

Chapter I

Some Assumptions

Assumption 1. That the striking of compressed air

Härtel, 1919, p. 270), gives essentially the same transcription. He does not list any other use of the same tablature.
is related to height or depth of pitch in almost the same manner as the division of vibrating strings into various parts. For just as the octave arises from the doubly rapid motion of one string in comparison with another, in wind instruments a doubly denser striking of air around the mouthpiece of the instrument necessarily also produces the octave. Thus, by the same token, if the density of the air were in the ratio of one and a half with respect to the first tone in any pipe, the fifth would be produced; if in the ratio of one and a third, the fourth; if three to one, the twelfth; if four to one, the double octave. And so it is with all the other consonances, which have been discussed at length above.\(^4\)

Assumption 2. That the material of which pipes are to be made must be especially homogeneous, and its surface smooth, for it can hardly be expressed how great a variation in sound is produced by an unevenness not even perceptible to the eye. For this reason, even the smallest grain of dust sticking to the pipes of the instruments makes cromornes sound out of tune.

Assumption 3. That the material of different pipes

\(^4\). Assumption 1 is an unsuccessful attempt to explain the production of different pitches in wind instruments. Kircher is not aware of the phenomenon and nature of standing waves in a column of air.
causes different sounds, so that it can correctly be said that the greater the difference in material, the greater the variation in sounds. And since the materials are infinite, we can safely assert that there is an infinite variety of sounds. For, as will be said in Part IV, there is no type of wood, metal, horn, or any relatively hard body, which does not sound differently, because of the different structure of its composition.

**Assumption 4.** That the varying constructions of pipes—length, width, arrangement of holes—cause various types of sounds as well as methods of playing. For this reason there emerges a variety and multitude of wind instruments, whose properties and use, especially of those that are more in use today, I have seen fit to discuss briefly in this place.

**Chapter II**

**The Classification of Wind Instruments**

As wind instruments are made to sound by the breath, they must all be hollow, and cylindrical or conical, or a mixture of these in shape, since a musical tone cannot be produced except by the agitation of the air enclosed in an instrument. The materials are most diverse. Some are made of the stems of reeds, or of goose quills, some of woods, of
the bark of trees, of the legbones and horns of animals, others of metals: lead, tin, silver, brass. Therefore the diversity of these lies only in their shape and materials.

First, then, the simplest of all are those which are made of the horns of animals, such as hunters and shepherds are widely accustomed to use; more about them later.

Second, immediately succeeding these are flutes made of reeds, an invention of ancient simplicity, for, taking the middle part of the reed, and putting holes in it, they aroused it into sounds. Later a more experienced age made such things of all sorts of wood, and they are mostly called *monauli* by the Greeks. By joining two, three, four, five, six, or seven of these into one they made up various systems called diaulic, triaulic, tetraulic, pentaualic from the number of pipes; the heptaulos or decaulos of Pan is also one of these.

Third are the flutes with several holes. In the first place after the monaulos are those that we call three-hole flutes from their three holes, four-hole from their four holes, five-hole from their five, six-hole from six.

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85. The *monaulos* and *diaulos* were double-reed instruments, those with three or more pipes (panpipes) were end-blown flutes.

86. The *galoubet* or taborer's pipe.
There are again the most diverse types of these, for they are either stretched straight out, or curved in the manner of a horn, or twisted into the appearance of a serpent, as it appears in the figure.  

Fourth, those constructed of brass drawn into a certain conical shape, are drawn out from narrow to broad openings, such as trumpets, which again are of various types, either with or without slides.

Finally, from all these simpler types, so to speak, organs are made, which consist of various registers and rows of pipes, and with bellows, connected to them through wind trunks, are made to produce the most perfect harmony by the industry of the organist, or by an automatic engine. There is again an enormous variety of all of these, which we will discuss more fully below.

§ I

The Galoubet

We will say nothing here of the monaulos, since its relation to the other flutes provided with many holes is that of the unison to the other consonances. And thus the galoubet, flauto, in Italian, is most suited for music, and

87. The flageolet.

has its holes so arranged that two in front, and a third in back governed by the thumb, suit the use and convenience of the flutist.

But what sort of tones it produces, or where this sort of flute turns in its ascent and descent, will be seen as soon as we have explained the fingerings of the flutist.

Thus, if the flutist wishes to produce the first note in the musical diagram below, he will close the three holes and blow the flute gently, and he will have what he sought. 89

(Note that black marks signify closed holes, white ones open.)

If he wishes the second note, he will close the two holes 1 and 2; if the third, one, the first; for the fourth, he will open all the holes. And he will be able to ascend this far with a continuous series of tones. But the fifth tone, which would be d, is impossible. Instead, he must leap over

89. The actual sounds are probably an octave above the notes indicated. The fingerings are copied from Mersenne. The scale on page 81 shows the notes corresponding to the lower row of fingerings, which, however, are erroneous.
the notes that follow after c, and will sound the fifth, that
is, the note g, with all the holes closed again, and blowing
more strongly. He will produce the sixth note, a, with the
two holes 1 and 2 closed. The seventh, b♭, he will have by
closing 1, with the third hole half open. All of this is
revealed most clearly by the present figure, in which the
black marks indicate closed holes on the flute, and circles
open ones, while the numbers 1, 2, 3 indicate the order of
the three holes in the flute AB, of which 2 and 3 are on the
front part of the flute, 1 on the back. These may be called
the notes of the lowest or grave tetrachord. Then, if anyone
wishes to continue the tones according to the notes
represented in the following scheme, he will find what he
sought by blowing harder, and closing or opening the holes
according to the signs placed below the figure of the flute,
the sign o half-closed indicating the semitone or flat.
Experience will teach clearly that these things are so. Why
we must jump a fifth after the fourth note in the above
figure, so that it is impossible to continue the tones in the
same breathing, could deservedly seem to be a paradox, if
everyday experience, as I have said, did not prove it.
Therefore, the reason for it remains to be investigated.
Why, in the Galoubet, after Four Steps, the Tones are not Continued, but a Leap of a Fifth is made from the Fourth Note

Nature puts certain limits on itself so rigid that it would be easier to destroy the world than to overstep them. These laws of nature appear in other things as well as in a definite condensation and rarefaction of air, which, when it strikes, produces one tone, not another, so that it seems to obtain its need with a definite measure. For let us observe that the longer and broader any channel or pipe is, the lower the tone it gives. The source of this fact is simply the volume of the space in which the air, set in motion by the breath, strikes the holes of the flute without condensation, and thus from its heavy and slow motion must give a low tone. So you see that in the three-hole flute under discussion, if all the holes in the side are closed, the lowest tone of all is produced, for when the holes are closed the length of the flute increases. Likewise when only two holes are closed, the length of the flute, as if shortened, rises one tone, the air pressure being, in accordance with Assumption 1, in the ratio of nine to eight with relation to the former air pressure.

Likewise, the flute rises one more tone when only one hole is closed, for if 2 and 3 are open the flute is made
shorter in effect, and consequently the air pressure increases; as a result of this, in accordance with my supposition, the pitch is raised, as mentioned.

Finally, if the flute has all its holes open, the pressure of the air is in the ratio of four to three with respect to the pressure when all are closed. In consequence of this, there must be a fourth between all holes open and all closed. Furthermore, since this flute does not have more than three holes, its ascent cannot continue by tones. Consequently, when all the holes are closed it is necessary to return to the first note by blowing as gently as before, or else it will sound the octave of the first, i.e., the fifth note in the above figure, while the breath has to increase to match the double pressure. From this discussion the cause of the diversity of sound in multi-hole flutes is clearly revealed. For this reason a hole only half closed must also give a semitone.90

90. Kircher's attempt to explain the production of various pitches on a flute comes close to hitting the mark, but fails because his basic hypotheses are faulty. He believes that a higher tone is the result of greater air pressure, and that the velocity in air of a higher tone is faster. While he recognizes the appearance of the harmonic series in the notes of the natural trumpet, he fails to notice the same phenomenon when it appears in the flutes. His faulty fingerings help explain this: if they had shown that the flute, with all holes closed, will overblow at the octave, twelfth, fifteenth, and so on, he might have reached a better conclusion, in conjunction with his correct observation that opening the fingerholes shortens the flute, in effect.
The Flageolet

We call the flute that has six holes in front the flageolet. The range of sounds produced in it reaches two octaves, as appears in the following scheme. 91

In this flute, because of the correct and uniform arrangement of its holes, there results a uniform series of sounds, as it appears from the above chart, in which the black circles indicate closed holes on the flute, the white ones open. In performing the first note all six holes are closed, since, with these closed, the flute has in effect the greatest length, and thus it must produce the lowest tone,

91. The last four notes are corrected from the original, where they are one step lower. The fingerings are slightly different from Mersenne's, but may be from a different source. Number 1 should show all holes closed.
for the reason indicated in the above section. And thus, as each hole is opened in turn, the pitch also proceeds by tones as the air strikes the flute in a certain fixed way, all of which would not take place if the air were not compressed with a sort of proportional progression; from this compression, it is necessary that the pitch be continually raised. You see also in this diagram that the tones do not ascend equally beyond the first hexachord, but change the plan of the progression of sounds after this point, until, in order to sound the octave, one holds the first open, the other five closed. In order to produce the octave, the blowing must be harder, and from here there is again a regular ascent for another octave. All of these things do not occur from any other cause than as a result of the varying modification of the air in the manner I have described, compressed and struck in this or that way by the closing and opening of the holes, as is most clearly shown in the arrangement of the diagram.

But if one were to arrange the holes of the flute so that two were located on the back and four on the front part, with an unequal distance between each other in relation to the way they are placed with respect to the others, he would find a great difference in the sounds and a different system of fingering. All of these things come about, as I
have said, only as a result of one and another arrangement of the holes, on which the air, consequently compressed one way and another, strikes.\textsuperscript{92}

\textbf{Explanation of the Instruments Contained in Plate IX}\textsuperscript{93}

Figure I shows a picture of the \textit{galoubet}, that is, the flute that has three holes, whose construction I have just explained.

Figure II shows the \textit{flageolet}, which has six holes, and which we demonstrated just above.

Figure III shows a recorder, which has nine holes. Since this type of flute is widely known, let us go on to others.

Figure IV shows a type of military flute, which the Germans are widely accustomed to use, in conjunction with a drum, and which the Swiss appointed to the Papal guard use. The application of this flute is different from the others,

\textsuperscript{92} The two arrangements of the holes of the \textit{flageolet} were known, one with all six in front, the other with two on the back for the thumbs. The figure, page 84, incorrectly has seven holes.

\textsuperscript{93} Not all the figures are included in the "Explanation". Figures VII and IX, the trumpet and trombone, are referred to in a later section. Unnumbered figures include two hunting horns, second from left at the bottom of the plate, and a bassoon reed, dolcian, and bassoon at the center left. There are no Figures V and VIII; Figures X to XVIII represent organ pipes and parts and will be discussed in the appropriate section.
Plate IX. Wind Instruments and Organ Pipes
for the flute is held across the lips, and it is blown at the hole X. See its tablature in Mersenne, Book Five, on wind instruments.

Figure VI shows the picture of a horn, cornetto in Italian, an instrument most suitable for the highest voice. But since these are very well known, we will not tarry over them.

But, so that I will not seem to have omitted anything, we will present here an ensemble of flutes, suitable for this class of instruments. For there are, as has been said above, compositions peculiar to each sort of instrument, which obtain their proper effect when applied to such ones and not to others.

Ensemble to be Performed on Flageolets, which are Called Flauto in Italian

94. The X is missing. It should be by the hole at the top of the figure.

95. From Mersenne, Harmonie universelle, p. 240, where it is entitled Gauotte pour les Flustes douces (recorders). The original has no bar lines; Kircher has supplied faulty ones, which have been corrected here. Note values have been halved.
You see that this composition is arranged with such skill that it obtains its effect only when performed on flutes; if it is performed on viols or lutes, it will not obtain it at all. Now we will join to these another composition to be played on four cornetts and another baritone instrument that they call dolcian or bassoon. How well it suits an ensemble of this sort, the reader will easily discern from the composition itself. 96

**Ensemble for Four Cornetts, to be Played together with a Dolcian, or in Italian, Fagotto**

96. From Mersenne, *Harmonie universelle*, p. 277, where it is titled *Phantasie à cinq parties composée par le sieur Henry le Jeune, pour les Cornets*. The bass was apparently intended for a serpent. For the dolcian, see below, p. 100. Kircher's version differs slightly from Mersenne's; Mersenne's variants are presented in small notes. The bar lines do not appear in Mersenne, are incorrect in Kircher, and have been corrected in the transcription. Note values are halved.
Since the cornetts attain a remarkable power in music, I certainly wonder that our Roman musicians take no interest in them, since nothing could be more suited to church music, especially if three, four, or five cornetts are accompanied by a bassoon. I certainly would think that ensembles of this sort, from time to time, would be much preferred to string ensembles for major solemnities and festivities, especially if they were shown off with compositions chosen for a style appropriate to them.

§ III

Trumpets and their Properties

The Holy Scriptures testify in many places that the trumpet is one of the most ancient instruments. We read in Numbers 10 that Moses made two silver ones at the command of God, and the Book of Judges records that Joshua used it as well. Also the First Book of the Kings shows that the trumpet was used before the Ark of the Covenant. But these matters are taken up in the treatise on the musical instruments of the ancients.97

In modern times trumpets form various classes. Some produce all different sounds only by means of the plectrum of the trumpeter's tongue, along with vigorous

97. Books II and VII.
blowing. Others, which are called the slide type, are so constructed that one [tube] can move close inside the other. In trumpets of this sort, the different tones do not emerge so much from breath and tongue as from lengthening and shortening, or what is the same, by pulling in or out the lower crook. These types are shown by Figures VII and IX of Plate IX. But let us examine first the properties of the first type, then of the second.

The trumpet has, among other hidden qualities, also this one, confirmed by the experience of all trumpeters, that the ascent of sounds can by no means be made stepwise, i.e., it is impossible that, for example, the tones re and mi follow the first tone; rather the second tone will infallibly be the octave, and the third another fifth, the fourth a fourth, and so on, as the following table shows.

\begin{equation}
\begin{array}{cccccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 8 & 9 & 10 & 12 & 15 & 16 \\
\text{octave} & \text{fifth} & \text{fourth} & \text{major} & \text{major} & \text{minor} & \text{major} & \text{major} & \text{minor} & \text{minor} & \text{major} & \text{semitone} \\
\end{array}
\end{equation}

98. I.e., the trombone.

99. Considerably revised from the incoherent form of the original. It was necessary to guess which tones Kircher intended, after the eighth harmonic.
In this table you see that the farther the numbers recede from unity, the more imperfect appear the consonances. The trumpet follows this natural progression of intervals. For, e.g., one first tone c gives the unison, so to speak, while it makes with the second tone, which is indicated by the number 2, not a second, but that consonance which the two numbers one and two express as its ratio, namely the octave. With the third tone, it makes not the major third, but that consonance which the ratio 3:2 has as its result, namely the fifth, and 3:1, or a twelfth, with the first. In the same way, from the fourth tone to the third is a fourth, and to the first, two octaves. Likewise the fifth tone makes a major third with the fourth, and the sixth a minor third with the fifth. Here, rejecting number seven as useless for musical purposes, it seeks another place by skipping. Then it goes gradually by tones and semitones as far as the twenty-ninth or quadruple octave, so that the trumpet has almost as many steps as the keyboard of the

The wonderful property of the trumpet.

The won­derful harpsichord in four octaves. But the creation of the tones to be produced by the trumpet is so clearly shown in the above scheme, that hardly anything but an examination by the eye is required. The only difficulty remains in the cause to be assigned to so many skips.
I say first, therefore, that it follows from the particular shape and construction of the trumpet, that the air must necessarily be moved twice as fast for the second tone as for the first. And because no other number falls between one and two, the instrument, as a result of the appetite fixed in it for pursuing an established goal determined by nature with just these numbers, will sound the octave. For the third tone, the fifth necessarily follows, since no other harmonic number can be inserted between two and three, and consequently the vibration of the air of the third tone is related to the vibration of the air of the second tone as two to three. In a not unlike manner, the air, aroused by the breath, gives the interval of a fourth for the fourth tone, since by a certain natural sequence the vibration of the air caused in each tone is in the ratio of three to four, which establishes the proportion of the fourth. You see, therefore, how much nature abhors dissonances, so that the trumpet would rather burst than allow them.

Thereupon, shunning the number seven as the enemy of harmony, it seeks the eighth as a friend for itself, with a sort of leap. You see also that the higher the trumpet ascends, the farther it departs from the more perfect consonances and approaches the more imperfect, until finally it proceeds by nothing but tones and semitones. And thus the
trumpet only follows the order of nature in numbers and sounds. The reason for this is no other than, as I said, to wit, the fact that the effort of the blowing of the trumpeter as well as the vibration of the air are in proportion to the numbers following the natural order.

From these things it is also apparent that in these six numbers the harmony of all things is founded, as will be said at more length in its own place. But that the trumpet proceeds by tones in its highest range happens because when the pressure of the breath is too great it cannot be increased except by the smallest intervals. For if it were continually increased by nothing but octaves, fifths, and fourths, the trumpet would necessarily exceed the natural limits of sounds. Since this would be contrary to nature, the trumpet moves and continues gradually from the largest intervals to smaller and smaller sounds, until it comes to rest at the limit fixed by nature, which is the twenty-ninth step, or, according to some, the thirty-second.

**Consequences**

From the above it follows that in originating sounds the trumpet exhibits the same rules in addition, as strings do in division. For in the same manner as a string divided in the middle sounds an octave above the whole, a
trumpet, by adding a second tone to the first, while making the air twice as aroused, similarly elicits the octave. Again, just as by the trisection the fifth is produced, similarly, by the combination of the three vibrations in the trumpet there arises the octave with the fifth, or the fifth. The rest can be explained in just the same way, and it was suitable to reveal all of it here in brief, so that the harmonic agreement of all things may be thoroughly noted.

Slide trombones have the same nature as military trumpets, with this exception, that by pulling out and pushing in, or reversing the slide, all tones in order can be produced, which we said could not be done in the other. For the lengthening and shortening of the slide has the same effect as the closing or opening of holes in flutes. Since all these things are clear, it is quite unnecessary that we linger any longer over them.

Finally there remains an explanation of the style of music that trumpeters perform on instruments of this type. For since, as I said above, all instruments require different styles of compositions, it will certainly be most obvious of an ensemble of trumpets. And it is established for four trumpets that the first of them carries the top part, indulging in various clausulæ and diminutions. Two others
take the middle road; the fourth, which they also call the
bourdon, remaining on a continuous unison, serves, as it
were, in place of a bass. There are those, moreover, who use
the trumpets that are called clarinas just the same as flutes
for any kind of ensemble, and perform the soprano parts
perfectly with all the diminutions displayed. We have
adjoined here a composition for two trumpets, the first of
which plays the notes of the present example, while the other
plays the same ones, but a third below, as they say, for thus
they harmonize marvelously, and achieve the most elegant
harmony.100

Example for Two Trumpets

The first of them plays this following composition as it is;
the other plays the same at the same time, but begins a third
lower, i.e., on d".

100. Following the instructions literally would require the
second trumpet to play c#" and b' a number of times; neither
is available on the natural trumpet; the b' would destroy the
clear D major tonality of Nos. II and III. A possible
solution would be to sound a' against e", f#' or the
unison against d". The rests, particularly at the beginning
of the second part of No. II, suggest the possibility that
the music has been taken from a composition for a larger
number of voices. The bar lines have been added, and two
corrections made as noted in No. III. In Examples I and III,
one beat is missing at the end of the last bar; in Example
II, two beats (correct if barred in 2/4 time).
§ IV

Cromornes, Cornemuses and other Bagpipes

Whoever has properly understood the workings of flutes with holes in the preceding sections will have no difficulty in understanding the production of sounds on the cromornes, cornemusus, bagpipes, and other similar instruments. Cromorne\textsuperscript{101} is the name given to a pipe curved in its lower part. It was an instrument especially used by the Egyptians, as has been shown elsewhere. Many use the name cornemuse for a bagpipe. What a bagpipe is is generally known, to wit, the only solace of shepherds and peasants. In this instrument an inflated bag, squeezed by the arm, causes the pipes joined to it to sound. These, in turn, produce various tones by various closings or openings of the holes. But a new instrument was invented not so long ago, which the French call musette. In this instrument, a bellows joined to it, when pressed and inflated, continually animates the pipes. It has almost countless keys corresponding to the various holes of the pipes, which the piper uses just as the keys on the harpsichord, for opening or closing the pipe holes. When wind is lacking, the distended bellows joined on below the arm is pressed, and thus a new wind is supplied by the bag to arouse the reeds. An instrument no less marvelous

\textsuperscript{101}. Kircher's name is \textit{lituus}, actually a curved trumpet.
to see than pleasant to hear.

Here at Rome I have seen an instrument of this sort not without a singular delight to my soul. And there are also other instruments in wide use that the French call **hautbois** and **fagots**. The one that Figure IX\(^{102}\) shows, I call the **choraulos**, others the **dolcian**, because they are made particularly for musical ensemble. But among them the one that is called **fagot** in the vernacular especially stands out; nothing sweeter or more fitted for playing the bass can be imagined. There is also the serpent, an instrument (such as this figure shows) used especially in France, very suitable for playing the bass. Although it surpasses the bassoon in the power of its sound, it is many parasangs,\(^{103}\) as they say, behind it in sweetness. Here you see its picture:

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102. Plate IX; actually an unnumbered figure second from the left of Figure IX.

103. An ancient Persian league. The word is used by various classical authors.
But this is enough on pipes with holes. Whoever desires a more exact description of all should read Mersenne, who has devoted a whole book of his *Harmonie universelle* to their description.

Not long ago my most sincere friend, the very noble and most intelligent man Master Manfredus Septalius, sent me another foreign flute-type instrument, whose picture we show here. It has five pipes, of which three, A, B, and C, are inserted in the axis FG, and the remaining two, D and E, seem to turn around in the axis. But what is its proper use can not be found out. 104 Now that the wind instruments have been

104. The figure seems to represent the drones and chanter of a bagpipe. These appear, however, to have mouth-holes like those of the fipple flutes.
described, nothing remains except for you to see the composition above, suitable and proper to a style of this sort, composed with the most beautiful artistry.105

Chapter III

Organs, and their Structure and Properties

The organ is like a sort of epitome and compendium of all wind instruments, and thus is deservedly the most beautiful and perfect of all. For whether you consider the variety of sounds, or the diversity of tropes,106 or the

105. The reference could be to any of the compositions for wind instruments, pp. 88, 89, or 97.
106. The meaning of the word is not clear; the sense may be "figurations".
multiplicity of voices, I certainly think that nothing can be compared with it. For who would not join Tertullian\textsuperscript{107} in admiring, in one machine, "so many members, so many parts, so many connections, so many paths of the sounds, so many collections of tones, so many interminglings of modes, so many rows of pipes, and yet all this a single structure," such that nothing could represent the machine, made with a sort of ineffable variety, that this world is, more beautifully than the organ, as will be said more fully in the \textit{Musica mundana}.\textsuperscript{108} And so it seemed fitting to describe in this chapter its various parts, the manner of its construction, and the proportions of the pipes, so that the aspects that we have treated separately might be explained here together.

\section{I}

\textbf{The Parts of the Organ}

The organ consists mostly of seven parts: 1, the bellows; 2, the wind trunk, in Italian \textit{portevento}; 3, the wind chest; 4, the sound board, that board full of holes in which the pipes are inserted; 5, the registers; 6, the pipes; 7, the pipes.

\textsuperscript{107} Ca. 155-ca. 222. The quotation, from \textit{De anima}, refers to the hydraulis.

\textsuperscript{108} Book X. See p. xxxiv for notes on Kircher's simile of the world and the organ.
7, the keyboard. Enough and more has been said about the keyboard in the chapter on harpsichords, for it is common to organs and all the keyboard instruments. For this reason, leaving it, we will proceed to a description of the pipes, and in the amazing description of this machine, we will make use of a natural order of proceeding.

The pipes used in the organ are very manifold, whether you consider their material or shape. They may be of wood, lead, or tin. Again, there are those that the Greeks call *calamos*, the Italians *flauti*, and there are *dulcianas*, flutes, trombones resounding in the manner of trumpets, and there are some imitating the human voice, which we not unfittingly call *anthropoglossas*.109

§ II

The Proportions of Open Pipes

Two kinds of pipes of this class are put in the organ, some open at the top, some closed; both merit much consideration in this matter. In open pipes, the proportion of length to width is not figured according to the diameter of the pipes, but according to the circumference, *i.e.*, the width of the sheeting from which the pipe is constructed, flattened out into the figure of a parallelogram. Thus, when

109. Greek, "human tongues," *i.e.*, the *vox humana*. 
flattened out, there appears as the surface AGCD what, when wrapped into a cylinder FGI, constitutes the pipe FG. And thus it is the proportions of the sheeting that are sought. And I may say that the proportion of the length of open pipes to their width is not so precisely mathematical that its slightest inaccuracy is harmful to the musical results, but rather has a certain latitude, for some take for the width $2/5$ of the length, some $3/5$ or even $3/4$.

The length of the cone of the pipe is unessential, for it serves for nothing but to carry the wind, causing the sound by striking the lip. The aperture of the lip IL must be a fourth of the circumference of the pipe, while the height of the aperture is figured similarly, and mostly as a fourth of the length of the aperture, while the segment must form an angle of twenty-two degrees with a right angle.110 Thus you have the proportion

110. The last statement is explained by reference to Mersenne (Harmonie universelle, "Livre sixiesme des orgues", p. 320), who says that the front face of the languid, immediately
of length to width of pipes described in a few words.

Closed pipes are different in two things from open ones: First, that the top of them is stopped up. Second, that two wings, which others also call ears, are placed on both sides of their mouths, for by bending them in or out, the sound is now released, now pent up, and they serve especially for perfect tuning of the pipes. Also the proportion of length to width is different; some make the length three times the width, and in pipes of the greatest length sometimes also in the ratio of seven to three or even eight to three. But in the smallest pipes the length is mostly made equal to the width, and a square sheet of lead is used.

§ III

The Systematic Proportion of the Pipes of one Octave

Before all, it should be known that the organs of this time are so constructed that they correspond perfectly to human voices. Therefore organists, pondering the matter more wisely, finally found that no measurement is more suited to human voices than if they make the pipes which sound F three or six or twelve feet in length, or even one and a half below the mouth, must be inclined at an angle of twenty-two degrees from the perpendicular, thus forming a wedge-shaped passage for the wind as it leaves the foot to blow across the mouth.
feet; for if you depart from this measurement, the organ must change, either a certain amount higher or a certain amount lower. Thus, if you establish the four octaves so that the pipe F of the first octave is twelve feet long, that of the second octave is six, of the third three, and of the fourth finally one and one half feet, you will have the organ established correctly. Recognizing these things properly, in this manner you will set up a perfect octave, or a system according to Caus.111

Problem I

How to determine the correct measurements of an octave system, or what is the same, the quantity and proportion required in organ pipes according to their octaves

Let us assume that in some system the pipe F is to be six feet long. We have represented it here112 with the letters FH. As it is in the fundamental position, you can obtain the quantities of all the rest with the least trouble, as follows.

First, let the whole length FH be divided into two equal parts at point f, and fH will be the length of the tube sounding the octave of FH.

111. Salomon de Caus, ca. 1576-1626. The reference is undoubtedly to Les raisons des forces mouvants (Frankfurt, Norton, 1615), "Livre 3, traitant de la fabrique des orgues."

112. On page 108 of the translation.
Second, so that you may have a pipe that will sound a fifth with FH, proceed so that FH is divided into three equal parts, marking the points.
Then two thirds, that is, CH, will be the length of the pipe sounding the desired fifth with FH.

Third, in order to obtain the fourth, do thus: divide the line FH into four equal parts, marking the points. Three fourths, or BH, will be the length of the pipe sounding the desired fourth with FH.

Fourth, in order to have the major
third, divide the whole line FH into five equal parts at points A, D, a, and aa. AH will be the length of the pipe sounding the major third with FH.¹¹³

Fifth, to obtain a major tone, divide all FH into nine equal parts, and eight of them will give the length of a pipe sounding the desired major tone with FH.

Sixth, DH equally divided into nine parts will give the length of the pipe EH sounding another major tone with the pipe DH.

Seventh, let AH be divided in the same manner into nine equal parts, and bH, eight of the parts, will sound a major tone with AH. With this effort you therefore have the pipes of one octave, represented by the notes FGABCDEFG.

Eighth, you will have the second octave if you transfer the lower octave divided in half, with all its parts, from f to ff, for this will be the second octave. You will have the third octave if you transfer a fourth of the space of the lower octave or half of the second from the point ff to fff. By halving we understand here dividing in the middle of each division, so that the lower octave with each of its spaces is the double of the second, and the quadruple of the third.

¹¹³. DH will sound the major sixth.
With the octaves arranged, you will find the remaining chromatic pipes, indicated on the keyboard by black keys, thus:

Ninth, in order to have the chromatic pipe C#, i.e., the chromatic step between C and D, which sounds a major third with A, divide AH into five equal parts, and the length C#H of the divided space will be the desired pipe sounding the major third.

Tenth, if you wish the pipe halfway between D and E, that is, the chromatic step D#, divide the line segment bH into five equal parts, and four of them will give the desired chromatic step, namely D#H.

Eleventh, if again you wish to have the chromatic step between G and A, namely G#, divide the line C#H into three equal parts, add to these one more such part, and you will have the part G#H, the chromatic step sought.

Twelfth, in order to have the chromatic step between f and g, let the part DH be divided into five equal parts, and four of them will give the chromatic step sought, namely f#H.

Thirteenth: You have here the chromatic steps of a whole octave. It is sought now how the chromatic steps of the other octaves can be had from these notes. I say in precisely the same very easy manner as above, for if you
halve each space of the first octave, and transfer the halves to the second octave, beginning with f, you will have all the desired steps of the intervals for the second octave. If you divide the spaces of the first octave in four, or those of the second octave in two parts, these parts transferred from ff will give the diatonic-chromatic steps of the third octave. Then the spaces of the third octave halved and transferred above fff establish the desired steps of the fourth octave. Therefore you see how each octave is divided into twelve equal semitones, and how all the pipes correspond to one octave on the keyboard. But consideration of the diagram reproduced here can teach you everything better than many words. 114

But you can divide these proportions into as many octaves as are required in the easiest manner by one single equilateral triangle, and with the greatest ease, in this manner: Let there be an equilateral triangle ABC, whose base BC is equal to Ff, the line of the first octave. Transfer onto it the various steps of said octave, as is seen in the figure, in order. When this is done, let the sides

114. The resulting scale will again approximate a just one in which all the chromatic steps except B♭ represent sharps. The semitones, of course, are not equal.

115. I.e., an equilateral triangle set up as described.
AC and AB be divided in half at E and D, and a parallel DE to the base BC be drawn. Again divide sides EA and DA in half at F and G, with another line FG drawn parallel to DE. Again divide the sides GA and FA in half at I and H, and draw the parallel line IH through them.

Having done this, if you draw straight lines to A from each point on the base BC, you will have an instrument prepared for increasing or diminishing the octave BC according to the given proportion. For if you join the
musically divided line DE in a straight line with the line BC, and join the line FG to the continued line DE, and the line HI to FG, you will have a pipe system for four octaves. In exactly the same manner, if you extend the radii from A to infinity, so that they are subtended in a parallel manner between the sides of a triangle, you can extend by this procedure almost to infinity a size the double of the preceding pipes.

Problem II

To Find the Width of Pipes

We know by this time that the width of the pipe is not that which is taken according to the diameter, but according to the circumference, or the sheet of the pipe extended to a flat surface. Therefore it is sought how this is to be assigned to each pipe. The procedure is as follows:

I. Take 2/5 of the whole line FH in the first figure of the octave, transfer them from F to N, so that FN stands at right angles to the line FH, for FN is the circumference of the largest pipe.

116. It will be necessary to add on another segment equal to IH, to correspond to the line from X (the highest horizontal line in the diagram, corresponding to the note ffff) to H in the preceding diagram.

II. Draw from point X a parallel XY to it, equal to XH. Then if you join the extreme points Y and N with a straight line, and draw from each point of the scale parallels to the line YN, they will give the proportion and measure of the pipes according to the width, or circumference.\footnote{NY has apparently been bent at 0 to conserve space. The circumferences determined by this procedure will gradually increase in proportion to the lengths, in accordance with the statement on p. 106 that in the smallest pipes, the circumference is generally made equal to the length.}

Problem III

To Construct a System of Stopped Pipes

We said in the preceding that there is a great difference between pipes open at the top and those stopped above. For they differ both in the proportion of the width and in sound. We will discuss these matters more fully in the following, when we assign the ratios of each. Now it is sought how a system of stopped pipes must be constructed. I say that the following rules are to be observed:

I. If one wishes to make a system a whole octave lower than the preceding, he will accomplish what he seeks if he makes all the pipes twice as long as those to which they correspond. And if you desire them a fifteenth lower than the preceding, all pipes should be four times as long. If a
twenty-second, or three octaves lower, all pipes will be eight times as long. These rules are mostly observed by all organists.119

II. The width of each pipe is found thus: First, to double the three-foot pipe in circumference, make the sides of the square SFEH equal to the line PY of the preceding figure of the octave. Then one diameter of this square, to wit, the diagonal line FH, multiplied four times in length, will give the line you desire, equal to the circumference of the pipe, as is demonstrated in Example 47, Book VII.120 For since the square ABCD is precisely the double of the square EFSH, then the circumference of the first is equal to the circumference PY of the pipe, and it necessarily follows that the circumference of the square BACD is double the square FEHS, and will also be the double of the circumference of the desired pipe.

Then if you desire to have the circumference of a pipe of six feet, you will obtain the desired circumference if you draw another square LMNO around the square ABCD, and

119. If Kircher is now talking about stopped pipes, we must assume that he was in Problem I also. Since a stopped pipe sounds an octave lower than an open one of the same length, stopped pipes twice as long as those in Problem I would sound two octaves lower, if Problem I referred to open pipes.

120. I am unable to locate such an example in Book VII.
if you desire the circumference of twelve feet, another square $VXYZ$ drawn around the square $LMNO$ will give what was sought, and thus you will be able to multiply the width of the pipes ad infinitum.\footnote{Kircher's intentions in these two paragraphs are thoroughly obscure. All we can do is to point out some of his mistakes and inconsistencies. His reference is to the figure on p. 108. No point $P$ is marked on it; he may mean to say $XY$, or perhaps $P$ is the midpoint of the line $XY$. The diagonal $FH$ will be $\sqrt{2}$ times the length of the original line, and four times the diagonal will be approximately 5.66 times the original line. If Kircher believed that the circumference of square $ABCD$ was twice that of $SFEH$, his qualifications as a mathematics professor are open to some doubt. The circles in the figure seem to have only an esthetic purpose.}
Problem IV

To Construct a System of Open Pipes

You will have a system of open pipes if you divide the lines XY and FN in half. These middle points, joined with a straight line, will give the desired circumferences or widths of all tubes included between those points, the lengths remaining the same as the preceding pipes.

Problem V

To Construct a Chimney Flute System

The chimney flute,¹²² a certain kind of pipe customarily included in organs, we so call because one pipe¹²³ is placed on top of another, for on pipe BC is placed another pipe BA, which the French call à cheminée. They are mostly of a louder sound than the rest described above; they differ in this and in tone. Therefore, if anyone wishes to construct a system of these, let him take first the length and breadth of the pipe D from the preceding system, which is a minor third lower than f, for this will serve for f; H-aaa will serve for ccc and

¹²². Or Rohr Flute, German Rohrflöte, French flûte à cheminée.
¹²³. I.e., the chimney.
thus between these two distances, all the rest of the lines will indicate the lengths of the other corresponding pipes. One fourth of the length of each pipe will give the circumference of the chimney pipe, and half the circumference of each pipe will be the length of the chimney AB.

Problem VI

The Nature and Structure of the Organ Wind Chest

The organ wind chest, which Vitruvius also calls the musical canon, is the principal member of the whole organ, and is called the secret because it hides the secret of the harmony from the listeners. It is a sort of receptacle in which the wind is contained, and to which are attached as many pallets (pallets are those valves which when open let the wind into the pipes) as there are keys to which they correspond on the organ keyboard. For if the keys of the keyboard are pressed, the stickers (for so we call those rods made of copper, iron, brass, and similar materials which are placed between the keys and the pallets) press down the pallets. As a result of this depression an entrance for the wind is allowed to those pipes that correspond to the keys

124. That is, each chimney flute pipe has the length of the closed pipe which sounds a minor third below.

and pallets. And so that the pallets will not remain permanently pressed down, there is a steel spring joined to them that forces them to their former position and closes the hole.

All of this can be clearly seen in the figures of Plate X joined here. Here, in Figure 1, in orthographic projection, XY denotes the wind chest, the letter L shows the key, GF the channel to the pipe, M the pallet, MH the spring, MI the sticker.\textsuperscript{126} In the perspective drawing, or Figure 2, L indicates the keys, M the pallets, LM the stickers. Key L, when depressed with the finger, pushes against the sticker IM of the pallet. When it is pressed, an entrance for the wind is opened through GF to the pipe corresponding to the key and pallet. Then from the depression of many keys and pallets in harmonic intervals, there arises that sweetest harmony by which we are delighted so much.

Problem VII

**Organ Registers, Wind Trunks, and Bellows**

Since there are various ranks of pipes in an organ, some containing open and stopped pipes, others flutes, others trombones and trumpets, some pipes imitating the human voice,\textsuperscript{126} The drawing is misleading: the pipe should be connected where the bellows are, and the bellows should lead directly into the wind chest, below the pallet.
Plate X. The Organ
and countless similar things, it is desirable, for a
diversity of sound, and according to the judgement of a
skilled organist, that all of these will not always sound at
once, but rather now this, now that, now this mixed with
these or those will produce music more pleasing in its
variety of sounds. For this reason, the greatest cleverness
of craftsmen has provided that certain things are made, one
for each of the ranks, like sort of retainers for the sounds,
and they are called registers. By these the arrangement of
the whole music is directed, varied, altered, expanded, and
diminished. But registers are nothing other than
What a
register is.
certain pieces of wood which have as many holes as
each rank has pipes. On pulling these, the lower
holes of the sound board of the wind chest are closed or
opened. But a picture explains the matter to the eyes better
than many words. CBAD, the upper part of the wind
chest (which we call the sound board), is perforated
with as many holes as the organ has pipes. The
registers corresponding to the various types of
pipes are P, O, N, and M. Each one of these is perforated
with holes to correspond perfectly to the holes of the table
lying below them. Therefore, if these registers are pulled
out by the handle T, the holes of the wind chest which lie
below are covered by them and stop the flow of the wind into
the pipes. We have shown the registers H, G, F, and E here not whole, but cut away, so that the table of the wind chest may be better exposed. But if you push back any of these, at once all the holes are opened, and produce the desired sounds. See the adjoining Figure 4 in Plate X.\(^{127}\)

Next, the wind trunks, which are called _portaventi_ in Italian, are wooden channels, of such a number as the size of the organ requires. These channels begin at the bellows, and are joined to them. According to the size of the machine, the number of bellows required is larger or smaller, and they have their particular proportions, which you may see in Caus and Mersenne; we have taken these things mostly from

\(^{127}\) The drawing is inaccurate, and should show M, N, O, and P lying in the same plane as H, G, F, and E, whose ends they are. Kircher neglects to explain several of the figures in Plate X. At the top is an organ prospect; its keyboard lacks the C and c'' of the standard four-octave keyboard with "short" lower octave. All the figures below are from Mersenne, who explains them in detail. Figure 3 shows the interior of the wind chest from directly in front; it shows the ends of the pallets, the springs, and between the pallets, pins to guide their motion. The figure at lower left shows a wind chest with two registers, one pulled out to show the holes underneath. The upper of the three unnumbered figures at lower right shows the table, which lies below the sliders. The next below is a _chappe_, apparently a large slider which moves between the two wooden strips on the table. The bottom figure shows several grooves from below. These are located in the top of the wind chest, and are ordinarily covered by the pallets. When a pallet is depressed, the wind passes directly from the wind chest through the groove into the pipes. The six grooves at right are covered with sheepskin to make an airtight seal with the top of the pallets.
them. I could bring in here many other things concerning the nature of the bellows that I have received orally from organists, but I omit them advisedly, so that we may not seem to occupy ourselves too much with mechanics and other commonplace things easily available to the public. Whoever still desires to know some more recondite things, let him consult the Magia musica,128 where we hope that without doubt we will have done enough for the curiosity of the reader.

Problem VIII

To Assign the Proportions of Reeds

Reed pipes are so called129 because they have tongues like those of animals, especially of birds, and consequently imitate human voices and those of other living creatures. They have two parts that fit together. See Plate IX, Figures 14, 15, and 16.129a

The first of these is BC, a semicylinder in the likeness of an open trough [i.e., the shallot], made of copper. The other is DE, a tongue made of a thin brass sheet, with which the open side of the shallot is covered. This shallot represents the lower part of the beak of a bird such as the goose, and the sheet its tongue. All this reed is inserted into another round piece

129. Kircher's word is Greek zooglossa, animal tongue.
129a. P. 87.
of wood A. So that the tongue may have the desired pitch, an iron wire FG is passed through the round piece of wood, and is twisted above so that it forces the tongue to lie in contact with the shallot, except at the top of the tongue, which must stand a little apart from the shallot so that the wind can enter to arouse the sound by the beating of the tongue. The pitch will be higher as a longer arm of the iron wire presses the tongue more tightly, lower as it presses it more weakly and loosely. From its effect we call the wire the tuning wire, because by means of it pipes of this type are tuned with each other. But see the figures placed here.

Now, since these things have been properly explained, nothing remains but for us to find the proportions of these reeds. This is done by observing these rules:

First: Lay off on any copper sheet the size of the largest shallot, which may be designated, for example, by the parallelogram ABCD, whose end is cut into three parts, so that when the sheet is bent into a semicylinder these end parts, bent into a bulge, can be joined better. See Figure XI, Plate IX.

Let the smallest shallot, i.e., this sheet to be bent into a shallot, be four inches long and one wide, and the smallest shallot will be one inch long and one quarter inch wide, as the parallelogram ILAE shows. You will find
the measurements of the rest in between as follows:

Second: Beginning from IL divide the line IC into fifteen equal parts, and when parallels are drawn to CD and AB you will have the desired lengths [from AB] of the fifteen others.

Third: You will find their widths in this manner: Divide LK in the same manner into fifteen equal parts, and line IL will give the width of the smallest; that following the smallest will have the width A₂, the third A₃, the fourth A₄, and so on with the others to the largest, which will have the width AB. But it suffices to mark off only sixteen shallots; for since there are forty-nine keys on a keyboard, i.e., as many as there are pipes, if you take three times sixteen shallots, that is, three equal ones of each size, you will have all the required shallots corresponding to the keys of the keyboard, for each one in the system takes care of three notes, although they are equal to each other. For the tuning wire, pressing on the tongues now more closely, now more loosely, easily corrects the length in accordance with the requirement of each case, and consequently the pitch. The diagram also shows the notes to which each one corresponds, e.g., three equal pipes must be made in the largest size; the first of these must serve for C, another for D, and a third for D#. The second triple pipe must serve for the
three notes G, G#, and A, and so on with the rest as the diagram shows. 130

Thus you see with what ease and at the same time pleasure proportions can be assigned to each reed. But now let us see in what manner trombones are to be made. 131

Problem IX

To Determine the Proportions of Vox Humana Pipes
(See Plate IX, Figures X, XVII, and XVIII. 131a)

There is still another kind of pipe that we not unfittingly call vox humana, for it nearly imitates true human speech and laughter, and brings such remarkable pleasure that in the whole organ system nothing is found more worthy of admiration, nothing that more vigorously seizes the spirit of the hearers. It is a pipe constructed of a reed and a tube not purely cylindrical, but conical-cylindrical, in which the reed is inserted. In the figure joined here, 132 ACFE indicates the conical part of the pipe, and FEML the reed. Its construction, and the proportions of the rest of the pipes succeeding in order, I will pass over with short

130. The engraving has been inaccurately copied from Mersenne (Harmonie universelle, p. 326). The cut-away section at the top is supposed to represent the largest shallot, serving for four pipes, C, C#, D, and D#, and there should be only fifteen others.

131. What actually follows is a discussion of vox humana pipes. Kircher does not discuss the making of "trombones".

131a. P. 87.

132. Figure XVIII of Plate IX.
rules as I was taught by Roman organists.

**Rule 1.** First lay off separately on a metal sheet the measurements of the largest and smallest vox humana pipes, in such a manner that the tube consists of two parts, a cylindrical one above, and a conical one below, while the whole tube is generally one half foot long. Then divide the whole length of the conical-cylindrical tube into fifteen equal parts, and give the conical part BDEF eight of them, while to the cylindrical part ACBD, whose diameter equals an inch, should be given seven of the fifteen. Two fifths of the diameter of the cylinder will supply the smaller diameter FE of the cone segment. Note here that this cone is of equal size in all the pipes. I have established a difference only in the cylindrical part, which for various shortenings gives various buzzings. But how this proportional shortening can be found, we will say.

**Rule 2.** Divide the cylindrical tube ACBD in Figure X into four equal parts, and one fourth BOVD together with the cone BDEF will give the smallest vox humana pipe. Then if you desire the rest in between do thus: Divide the side OA or VC into twelve equal parts, and you will have what you sought. For T2FE will give the next to the smallest pipe, S3FE the third, X4FE the fourth, and so on with the others to the twelfth. In addition, each one of these is trebled, so
that for the whole rank each one serves for producing the notes written by each line determining the height of the pipe.\textsuperscript{133}

\textbf{Rule 2.} From the largest vox humana tongue ILMN and the smallest LH of Figure X, you will find the proportions of the rest of the tongues in this clever manner: The largest tongue ILMN will be three inches long, and the last or smallest HL two thirds of an inch. And so if you lay off a three-inch line, two thirds of an inch taken away from it will leave HL as the least. If this is taken away, the line HN will remain. Divide it into twelve equal parts, and the lengths of the tongues will proceed, gradually decreasing in the same manner as before, in the conical-cylindrical pipe, the lengths of the rest of the pipes corresponding to the lengths of the tongues did. Each one of these lengths, tripled,\textsuperscript{134} produces the sounds that the notes written by the

\textsuperscript{133} In order to make the diagram agree with its description, the letters 0 and V should be shifted up one line. Then the notes below each line would correspond correctly. The next lines above T should be marked S and X, those above V, 2, 3, and 4. Each size is actually made to serve for four, not three pipes, and the largest one presumably for five (C and C\# in addition to those noted). The line by which the engraver has marked the 0 and V was intended merely to show that the width of the cylinder is to the width of the bottom of the cone as 5:2. When 0 and V are correctly placed, the sides OA and VC are divided into eleven equal parts, not twelve.

\textsuperscript{134} Or rather, quadrupled.
corresponding pipe lengths indicate. Then you will find the width of vox humana tongues if you divide the width of the largest into eight equal parts, for one eighth, or \( \frac{1}{8} \), will give the width of the next tongue after the smallest; two eighths will give the width of the third vox humana tongue, and so on with the others, as the diagram shows.\(^{135}\) But the figure will instruct you better in everything. Note that divisions of this sort are not geometrical but merely mechanical ones developed by the long experience of builders.

**Problem X**

**To Construct a Diatonic-Chromatic-Enharmonic Organ**

This type of organ consists in the arrangement of a diatonic-chromatic-enharmonic keyboard. Since enough has been said about it in the chapter on harpsichord keyboards, I omit discussing it here, since all those things can be applied here. A new proportion of pipes is not necessary for such minute intervals; the smallest intervals can be had even from equal pipes in the easiest manner, by merely adding to or subtracting from them. All these things are too clear to need further explanation. But whoever desires to know more

\(^{135}\) From the diagram it appears that what Kircher should have said is that the width of the smallest tongue will be three eighths that of the largest, that the next tongue will have the same width, and that the next two sizes will add one eighth to the width, and so on.
on automatic organs should consult the "Magic of Consonance and Dissonance", where we adorn this mechanical organ with amazing devices.136.

Part IV

PERCUSSION INSTRUMENTS

Finally we begin the fourth part of "Instrumental Music", which is on instruments that are made to give forth a tone by striking them. Although there is hardly any body in nature that is not capable of some sound, as was discussed at length in Book I, we are taking up in this place the more sonorous bodies; these may be of the most porous and lightest wood, as are wooden rattles of all sorts; likewise of harder metals, as all sorts of big and little bells, cymbals, castanets, and systra; or of skins stretched over a hollow body, as drums of all types, etc. We will discuss each briefly in this part, so that the cause of the sound and the manner of construction to be observed in each one may be noted more clearly.

Chapter I

The Sounds and Harmony to be Obtained from Pieces of Wood

I have said that there is no body that does not have its own sound, as has been fully shown in the "Physiologia musica". For if you work woods of all kinds, first purged of all moisture, into cylinders or parallelepipeds, you will find that each wood, just as it has a different composition, will produce a different tone. In order to make a perfect experiment in this matter, I had made wooden parallelepipeds of oak, beech, cyprus, ivy, pear, apple, linden, pine, fir, elm, poplar, cherry, walnut, ash, cornel, plum, ebony, almond, willow, and fig, all of the same size. In all of them I found, with diverse weight, also diverse sound.

Comparing these also most carefully with the experiments made by Father Mersenne, I found that they differ much in weight as well as in sound, although I adhered absolutely to all the conditions prescribed by said Father. The reason for this fact can be only perhaps the more perfect maturing of the woods of this Roman climate and their greater dryness, which makes wood weigh less and sound higher, in the manner that we also demonstrated for strings in the first

part of this book. For there must be no doubt that various climates cause one and another constitution in woods, as we have demonstrated amply for plants, fruits, and animals also in our *Anacamotica*. Accordingly, no one should wonder if experiments made at Paris and here at Rome do not agree in everything. For the more regions approach the North, the more humid a nature they receive, which is always followed by a lower and lower pitch. For example, the Roman willow is much drier than the Parisian, while the Roman palm is much damper than the African. The same can be said of the others. But so that you may grasp in one glance the differences of both observations made here at Rome as well as at Paris, it seemed right to add this table, representing each of them.

138. No publication of Kircher's has such a name. Perhaps it refers to a chapter of some work.

139. The weights used by Mersenne and Kircher correspond roughly to our apothecaries' weight, in which one ounce equals 8 drams, and one dram equals 60 grains. In the old French system, which is used in the table, one *once* equals 8 *gros*, while one *gros* equals 72 *grains*. The *once* (30.528 grams) is also slightly smaller than the apothecaries' *ounce* (31.10 grams). The weight of the maple has been corrected according to Mersenne's table (*Harmonie universelle*, "Traitez de la nature des sons, et des mouvements de toutes sortes de Corps", p. 183). In the original table, the pitches are presented on musical staffs.
Table Demonstrating the Weights and Differences in Pitch of Various Types of Wood

<table>
<thead>
<tr>
<th></th>
<th>According to the observations of Marin Mersenne</th>
<th>According to the observations of Athanasius Kircher</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight (oz. dr. gr.)</td>
<td>Pitch</td>
</tr>
<tr>
<td>Pine</td>
<td>0 3 55</td>
<td>d''</td>
</tr>
<tr>
<td>Willow</td>
<td>1/4 0 43</td>
<td>b'</td>
</tr>
<tr>
<td>Sycamore</td>
<td>1/2 0 5</td>
<td>g'</td>
</tr>
<tr>
<td>Maple</td>
<td>1/2 0 23</td>
<td>a'</td>
</tr>
<tr>
<td>Walnut</td>
<td>1/2 0 33</td>
<td>g'</td>
</tr>
<tr>
<td>Cherry</td>
<td>1/2 0 32</td>
<td>b'</td>
</tr>
<tr>
<td>Pear</td>
<td>1/2 1 5</td>
<td>a'</td>
</tr>
<tr>
<td>Hornbeam</td>
<td>1/2 0 69</td>
<td>a'</td>
</tr>
<tr>
<td>Oak</td>
<td>1/2 0 59</td>
<td>a'</td>
</tr>
<tr>
<td>Cornel</td>
<td>1/4 1 10</td>
<td>e'</td>
</tr>
<tr>
<td>Ivy</td>
<td>1/2 0 44</td>
<td>a'</td>
</tr>
<tr>
<td>Alder</td>
<td>1/2 0 10</td>
<td>b'</td>
</tr>
<tr>
<td>Ebony</td>
<td>1 5 10</td>
<td>a'</td>
</tr>
</tbody>
</table>

With all of these woods most carefully worked into the form of equal parallelepipeds 5 inches, 6 1/2 lines long, 1/2 inch wide, and 1/2 inch thick, and then most exactly.\[140\]

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140. A line equals 1/12 inch. The measurements are given here after Mersenne; Kircher's text at this point is obscure, and in any case his figures are not correct, if they are to agree with Mersenne's.
weighed by a pharmacist of the Collegium Romanum, I found the weight of each one to be as given in the above table. Yet it is remarkable that we do not agree in any, except the ebony. The reason for this is that the ebony does not grow in the climate of Rome or of Paris, but of India, and is therefore equally subject to a climate of the very greatest dryness. From this you will gather how much I differed from Mersenne in my experiments, in weight as well as in pitch, and you will wonder that in such an uncertain business we agreed so much that we did not deviate by as much as a single ounce, much less a tone.\textsuperscript{141} But that we did not precisely agree, is to be ascribed to the diverse constitution of woods, which I showed a little while ago. See our most detailed account of these matters in our "Physiologia musica",\textsuperscript{142} and in the first book, on the causes of sound.

Furthermore, we also had metal parallelepipeds made, which are, of course, much more exact and more sonorous than wooden ones. We had them made of tin, iron, and copper.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin</td>
<td>All of them, equal in size, when struck produced sounds as shown by the table.</td>
</tr>
<tr>
<td>Iron</td>
<td>141. According to the table, Kircher is incorrect here: most of the pitches differ by at least a tone, one by a minor third, and three by a major third.</td>
</tr>
<tr>
<td>Copper</td>
<td>142. Book IX, Part I, of Musurgia.</td>
</tr>
</tbody>
</table>

\textsuperscript{141} According to the table, Kircher is incorrect here: most of the pitches differ by at least a tone, one by a minor third, and three by a major third.
Since I do not have gold and silver, it was not possible to include them also in the experiment. Note also that not only in woods, but also in metals there is the greatest diversity of sounds. For among themselves they exhibit three different pitches. The reason for this is precisely the inequality of the material of the wood as well as of the metal; their composition and the like are of one sort and another; we can comprehend these things better with the reason than with the senses. We have found this diversity in all mixed metal bodies, as is said in the following.

Experiment

To Construct a Xylorgan

What we call a xylorgan here is an instrument in which, instead of pipes, wooden cylinders or parallelepipeds are arranged musically so that when a skilled player presses the keys of a keyboard, they strike the wooden bars with their hammers, and thus cause a kind of musical clanking. Much has already been said about the keyboard; it remains for us to continue with the rest of the construction. And so let there be made of an especially resonant wood, with a smooth surface all over, wooden cylinders or parallelepipeds, twenty-six in number, for these will just fill out two octaves, each one of which is thought of as divided into thirteen semitones, as has been fully demonstrated in the
preceding sections. The proportion of the wooden bars will be the same as the proportion of the pipes which we gave in Chapter III, Problem I. These bars are arranged on top of some hollow vessel, so that they touch it only on a line. Then hammers are fitted onto the ends of the keys, and the organ is constructed.

Some manage the construction of the bars more mechanically, in that the largest bar is made in a double proportion to the smallest, while the rest in the middle get smaller by a proportional decrement such that they perfectly present the systems of any whole octave.

We illustrate the instrument here, so that at a single glance what is to be performed in connection with this matter may be clear to the curious reader.

143. The number of bars would actually be twenty-five; there are, of course, only twelve semitones in an octave.

144. Actually, the pitch of solid bars increases inversely as the square root of the length, other factors being equal; thus a rod half as long will be two octaves higher.
**Explanation and Use of the Instrument**

The wooden bars placed in order, representing the pipes, are AB. The keys are CD, on whose end are attached the mallets; GV is one of them. FE is the hollow vessel having on top two No. 6 metal wires, on which the bars mentioned gently rest, arranged and fastened in musical order. And it happens that when anyone presses the keys in harmonic intervals, they strike the bars with the mallets, while the sound of the musically arranged bars gives a not unpleasing harmony, which is very greatly increased by the underlying hollow body. We have placed one key with its mallet separately here for better understanding. GV indicates the key, V the mallet fixed on its end, R the bar placed above. The same is to be said of the others.

**Corollaries**

From this machine it is clear that all earthly bodies arranged in such a way can produce music. The more resonant bodies are, the better the effect they obtain. If one were to construct similar parallelepipeds or cylinders of resonant metal, or even fit on bells of various sizes, of bell metal, glass, and other materials, instead of wood, he would achieve new tones with all of them. An instrument could be made, constructed of wooden bars of this sort, little bells, and glasses musically arranged, on whose keys
there would be as many mallets as tonal systems. The first mallet would strike the wood, the second the little bell, the third the glass vessels, the fourth the other bodies arranged as the present figure clearly shows, in which A indicates the wooden parallelepiped, BE the little bell, CD the glass vessel, G the key, D, E, and F the mallets. Then when the key G is pressed, the mallets, striking the various types of vessels, will produce various tones. Some construct an instrument like this without keys, but place wooden bars in musical order over straw or the two above-mentioned metal wires, then easily perform with a mallet whatever they wish. Examine the instrument of wooden bars shown here.\textsuperscript{145}

\begin{center}
\includegraphics[width=0.5\textwidth]{xylophone.png}
\end{center}

Not so long ago, in order to dispel the melancholy of some great prince, a noted and ingenious actor constructed an instrument such as this. He took live cats all of different sizes, and shut them up in a kind of box especially made for this business, so that their tails, stuck through holes, were inserted tightly into certain channels. Under these he put keys fitted with the

\textsuperscript{145. The xylophone.}
sharpest points instead of mallets. Then he arranged the cats tonally according to their different sizes, so that each key corresponded to the tail of one cat, and he put the instrument prepared for the relaxation of the prince in a suitable place. Then when it was played, it produced such music as the voices of cats can produce. For when the keys, depressed by the fingers of the organist, pricked the tails of the cats with their points, they, driven to a rage, with miserable voices, howling now low, now high, produced such music made of the voices of cats as would move men to laughter and even arouse shrews to dance.146

Chapter II

Bells, and their Construction and Use

Among all the percussion instruments, the bell certainly obtains the principal place, whether you consider its power of tone or its pleasantness. Since its origin has

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146. A favorite story of the fifteenth to eighteenth centuries. See Jakob Adlung, Anleitung zu der musikalischen Gelahrheit (Erfurt, 1758, p. 574) for several references. According to Jan Bouchet (Annales d'Aquitaine, Poitiers, 1557; f. 164), such an instrument was constructed by the Abbé Baigné for Louis XI of France (1423-1483), but with pigs instead of cats. A drawing by Johann Kellerthalcer, Jr. (fl. 1550), engraved by Jacques Callot (1592-1635), of a concert of madmen shows an instrument of a similar nature (reproduced in Robert Haas, Aufführungspraxis der Musik, Wildpark-Potsdam, Athenaion, 1931, p. 210).
been discussed elsewhere at length, I wish to be rather brief here. Polydore Virgil\(^{147}\) notes that it certainly was first invented in Campania; consequently it has kept the name of campanian bronze,\(^{148}\) and a little bell the name nola,\(^{149}\) even to this day. Some ascribe it to the Egyptians, who, beating bronze shaped into some sort of hemisphere at the feast of Osiris, together with sistra and rattles, made everything resound. These things are discussed at length in the description of the Egyptian sistrum in our Oedipus.\(^{150}\) Also we have clearly shown in the treatise on musical instruments of Schilte Haggiborim\(^{151}\) translated by us from Hebrew into Latin, that it is most ancient and was used in the earliest times by the ancients. It is also known from the Hebrew Antiquities of Josephus.\(^{152}\) thus there certainly can be no

\[^{147}\text{Ca. 1470-1555. The reference is probably to De inventoribus rerum, Paris, 1499.}\]

\[^{148}\text{I.e., bell metal. Curt Sachs (Reallexikon der Musikinstrumente, Berlin, Julius Bard, 1913, pp. 70-71) says Campania is not the source of the name; rather, it is related to Greek }\hat{\alpha}d\mu\pi\nu\omega, \text{ to bend.}\]

\[^{149}\text{A city in Campania.}\]

\[^{150}\text{See above, p. xxxv.}\]

\[^{151}\text{Quoted extensively in Book II of Musurgia. A translation by Blasius Ugolinus was published in Vol. XXXII of his Thesaurus antiquitatum sacrarum (Venice, 1744-1769).}\]

\[^{152}\text{A.D. 37 or 38-100. Antiquitates Judaicae, 93 A.D.}\]
doubt of its antiquity; the only difficulty that remains is on the matter of its material and shape. And although among many peoples bells of various wooden forms such as we make use of in Holy Week are used even for summoning the people, we mostly choose those made of iron and bronze. See what the most learned Roman Joannes Baptista Casalius says about these things in his work on the rites of the old church. But modern artisans, taught by wide experience, make bells neither of pure iron, nor of pure bronze, but from a certain mixture in a certain and definite form, and they produce that remarkable tone at which we rejoice. For this reason, leaving all other methods of the ancients, we have seen fit to discuss briefly the proportions that more recent artisans obtain in the mixture as well as in form.

The Mixture of Bell Metal

The artisans who wish to found bells of better tone do thus: they take three, four, or five parts of fine copper and in addition one part of English tin. But those who put twenty pounds of tin to a hundred pounds of copper make remarkably uncertain bells. Experience has taught that the preceding mixture makes a better effect. Nothing in this field can be prescribed with a sure word, but rather the

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whole business is to be entrusted to experience, which has taught that various mixtures are required for bells of various sizes. For casting little bells, bell-founders take one third of a part of tin to ten of copper, by which they are made especially sonorous. Some also add silver for clarity of sound as well as ease of melting. In many places in Germany I have even seen bells as large as any, of the clearest and most limpid tone, which they say were cast of pure silver, which, however, is hardly credible, since silver without anything added can hardly be made to show such a clear and limpid tone; therefore some copper, tin, or bronze must be added. But all these things should be left to the judgement of the prudent founder.
The Shape of Bells

The shape of bells in Italy is mostly that of the figure that precedes. Its thickness, length, and width are as follows: First, Italian founders take the extreme edge IK of the bell for a basis, i.e., that part which is struck by the bell's hammer, and which must be thicker than the rest to withstand the blows of the hammer. They transfer the thickness of this part, repeated as many times as they wish, to a straight line as a sort of scale, and then they take fourteen of these parts for the length, or height of the bell, as RV shows in the figure; while for the greatest width of the bell they take six and a half parts of the height on each side of R, and for OL the lesser width of the bell they take three and a half on each side of the middle line VR, so that the maximum and the minimum width are in double proportion. But in France and Germany the height is generally made twelve times the thickness of the wider edge, which they determine thus: The thickness of the edge or lower zone IK having been determined, it is diminished in a proportional decrement from IK towards MN to two thirds of the thickness, so that at MN there is two thirds of the thickness of the edge IK. Then from IK to nine parts of the height let the thickness be three sevenths that at IK. From here to the twelfth part of the height let the thickness be one half that
of edge IK. From here to the handle of the bell the thickness of the bell increases proportionally according to the table given here. But all these things are to be established not so much by geometrical ratios as by practice itself and experience.

Italian founders determine from the following figure alone all proportions of length, thickness, and weight to be employed in a bell. You see where, first, AB indicates the thickness of the edge of a bell weighing 10,000 pounds, EF the thickness of the edge of a bell weighing 9,000 pounds, and thus you see the thickness of the edge

### Table of the Thickness of a Bell

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>IK</td>
<td>1 part</td>
</tr>
<tr>
<td>NM</td>
<td>2/3</td>
</tr>
<tr>
<td>QX</td>
<td>3/7</td>
</tr>
<tr>
<td>OL</td>
<td>1/2</td>
</tr>
<tr>
<td>OVL</td>
<td>3</td>
</tr>
</tbody>
</table>

154. The value for OVL is in error, and was probably intended to be 2/3.
of the bells continually more diminished in accordance with their smaller size and weight, up to the smallest one, of ten pounds, which has the thickness CD. Then you will determine the proportions of the remaining parts of the bell from the thickness according to the table presented just above.

The Tongue or Clapper of the Bell

What the tongue is in the mouth, the clapper is in the bell, and therefore it is especially necessary in bringing out the sound. Its proportion is of such importance that if it is less than the proper one, it produces a highly imperfect tone, if larger than proper there is danger that it will crack the bell with its impetus and the violence of the striking weight. Therefore we will show by numbers written beside each number of the preceding table what proportions founders are accustomed to apply to the clapper of a bell whose weight has been determined.\(^{155}\)

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\(^{155}\) The weights do not closely correspond to those of the preceding table; the series has been extended to 22,000 pounds, and the weights from 10 to 10,000 pounds are mostly different.
Table of the Proportion of Clapper and Bell

<table>
<thead>
<tr>
<th>Weight of bell in pounds</th>
<th>Weight of clapper in pounds</th>
<th>Proportion of clapper to bell</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>27</td>
<td>6,500</td>
</tr>
<tr>
<td>700</td>
<td>30</td>
<td>7,000</td>
</tr>
<tr>
<td>800</td>
<td>34</td>
<td>7,500</td>
</tr>
<tr>
<td>900</td>
<td>37</td>
<td>8,000</td>
</tr>
<tr>
<td>10,000</td>
<td>42</td>
<td>9,000</td>
</tr>
<tr>
<td>12,000</td>
<td>46</td>
<td>9,500</td>
</tr>
<tr>
<td>14,000</td>
<td>52</td>
<td>11,000</td>
</tr>
<tr>
<td>16,000</td>
<td>63</td>
<td>12,000</td>
</tr>
<tr>
<td>18,000</td>
<td>67</td>
<td>13,000</td>
</tr>
<tr>
<td>19,000</td>
<td>75</td>
<td>14,000</td>
</tr>
<tr>
<td>20,000</td>
<td>80</td>
<td>15,000</td>
</tr>
<tr>
<td>22,000</td>
<td>100</td>
<td>16,000</td>
</tr>
<tr>
<td>24,000</td>
<td>125</td>
<td>17,000</td>
</tr>
<tr>
<td>26,000</td>
<td>140</td>
<td>18,000</td>
</tr>
<tr>
<td>28,000</td>
<td>145</td>
<td>19,000</td>
</tr>
<tr>
<td>30,000</td>
<td>150</td>
<td>20,000</td>
</tr>
<tr>
<td>32,000</td>
<td>160</td>
<td>21,000</td>
</tr>
<tr>
<td>34,000</td>
<td>175</td>
<td>22,000</td>
</tr>
<tr>
<td>36,000</td>
<td>190</td>
<td>23,000</td>
</tr>
</tbody>
</table>

You have here almost everything that could be desired in this matter, for we have extended the table to a bell of 22,000 pounds, the largest of all that are being made in Italy at this time. For just as the larger ones turn out to be unsuited for striking, so they also give forth a duller sound, as is clear from the bell of Erfurt, the largest, if I may say so, not only of all Germany, but of the whole world. I will describe its prodigious size a little below. Indeed, in France there are huge bells that Mersenne mentions, such as the one that is to be seen at Rouen in the tower of the Blessed Virgin, of 33,000 pounds, and about eight and two thirds feet in diameter; at Lyons in the tower of the Church of St. John, of 28,000 pounds; and in the Church of Notre Dame at
Paris, of 23,000 pounds, and seven and a half feet in diameter; of St. Martin at Tours of 25,000 pounds. But that of Erfurt, the queen of all bells, deservedly surpasses all of these.

The Size of the Prodigious Erfurt Bell

One fourth of a German ell

One fourth of our German ell, which taken four times makes a whole ell, of which there is mention in the following description. A German ell of this sort contains two geometric feet.

An Accurate and Faithful Description of the Greater Bell of the Collegiate Church of the Virgin Mother of God at Erfurt, and Memorable Things that Concern it

Various bells of both Collegiate Churches at Erfurt (I mean of the Virgin Mother of God and of the nearby St. Severus), which are large and sound well together, bring much majesty and ornament to that place. One stands out among these, the most celebrated far and wide, which should be seen for its size and weight, as well as its sound and the elegance and artistry of its form, the greater one of the Church of the Blessed Virgin, occupying the middle of the tower alone among three others like companions, the Queen of Bells, with four smaller ones hanging above like a crown.

This famous bell was cast by the distinguished craftsman Gerard Wou de Campis (whose name can be read on it) in the year of Christ 1497; the expenses were liberally contributed by neighboring princes, primates, and citizens of Erfurt.

It was dedicated to the honor of the

156. The line is 5.7 inches long, making a German ell 22.8 inches.
Glorious Virgin MARY, from whom it obtains its name, and is called "Gloriosa". In the secondary ornaments on the upper part it displays lilies, on the lower, oak leaves, separated by twelve circles. The epigraph or inscription is as follows:

"I sing the glorious praise of my patrons, warding off the lightning, and I drive off malignant demons from the people in the churches by sounding my holy song."

The weight of the bell is, according to the testimony of a bronze founder, 252 hundredweight.

The largest thickness of the lower part is one and a half times a quarter ell.

The height including the ears is five ells less a quarter. Measured in a straight line without the ears, the height is four ells less a quarter.

The diameter contains four and a half ells, and one sixteenth ell more. The exterior circumference is fourteen and a half ells at the lowest part, in the middle nine and one sixteenth ells, at the top part eight and one sixteenth ells.

In addition to the middle and principal ears, it has seven placed around the top, any one of which weighs a hundredweight and is a quarter ell thick, less a finger's breadth.

The clapper of the bell is four ells long. Its thickness, at the lower part with which it touches the bell, is an ell and two and a half quarters; its weight, according to the estimate of bronze founders, eleven hundredweight.

Any joint on which it is moved weighs 157. Actually less than the weights of two of the bells above, pp. 146-147.

158. The clapper?
three quarters of a hundredweight.

In order that it may be fully heard and sufficiently struck, it must be rung by twenty-four men, in addition to whom two others are required to drive the clapper from both sides.

The sound of the bell when struck, when carried by a favorable wind, is easily heard at Gotha and Weimar (both cities are three German leagues\textsuperscript{159} from Erfurt). Curriers and post-coachmen affirm that sometimes it is even heard at four miles.

It emits a sound very low and magnificent, which, according to the testimony of organists, corresponds to the lowest D.\textsuperscript{160} It makes this most pleasing sound with the consonance of a third which is perceived to be mixed with it, and establishes the interval DF.

The ordinary price for ringing it, when it is rung alone for a funeral or some other purpose, is one Philippic or Royal Taler. But when it is rung together with the rest of the bells of the two adjoining towers, five Imperials are paid.

I swear that all these things are so, and have been found out as reported in this description after faithful and accurate investigation, measurement, and observation, and I testify with the signature of my name Urbanus Heun Count Palatine, Seal-bearer of the Most Eminent and Reverend Archbishop of Mainz, Electoral Prince of the Holy Roman Empire, Dean of the Collegiate Church of the Blessed Virgin Mary at Erfurt, and Pro-chancellor of the University at the same place.

\textsuperscript{159} A German league (the same as the mile mentioned in the sentence below) was approximately four and a half English miles.

Problem I

To Construct a Carillon, in which the Size of the Diameters of any Bell is Found

We give the name carillon to a certain collection of bells so constructed according to musical proportions that, when rung according to the rules of the keyboard, they produce a given harmony. You will achieve this system, which is also called a bell scale, thus, according to the rules of Italian artisans:

Rule 1. Let the diameter of the largest bell be AB. Divide this first into ten equal parts, and nine of them will give the diameter of the second bell sounding a minor tone above the first. Let CB again be divided into ten equal parts, and nine of them will give the diameter of the third bell sounding a tone above the second, and consequently these three bells will sound a major third ut, re, mi, which, however, as we will see later, is faulty.

Rule 2. In order to have a bell which will sound a fourth above the first, divide the segment DC into five equal parts, and three of them laid off from D toward B will give at E a point which determines the diameter of a bell sounding a fourth, i.e., BE.

Rule 3. In order to have a bell which sounds a fifth with the first, do thus: Let the diameter of the
fourth BE be divided into ten equal parts, and nine of them will give BF, the desired diameter of the bell. Again let this be divided into ten parts, and nine of them will give the desired bell BG, the diameter of one sounding a sixth above the first. Further, if BG is divided again into ten parts, nine parts will give BH, the desired diameter for bell seven.

Rule 4.
You will have a bell sounding an octave above the first if you divide diameter AB in half at
I, for IB will give the diameter of the bell sought.

This is the imperfect method of artisans, since in the first place they make a major third of two minor tones. But whoever will manage the business according to more exact rules of music, let him observe these things:

First, divide AB into ten equal parts, and nine of these will give the diameter of the second bell.

Second, divide BC into nine equal parts, and eight of these will give the diameter of the third bell, sounding a major third.

Third, divide AB into four equal parts, and three of these, or BE, will give the fourth bell.

Fourth, divide AB into three equal parts, and two thirds, BF, will give the desired diameter of the fifth bell.

Fifth, divide BC into three equal parts, and two thirds of BC will give the diameter of the sixth bell.

Sixth, divide BF into five equal parts, and four of the five, namely BH, will give the diameter of the seventh bell.

Seventh, divide BA into two equal parts at I, and IB will give the diameter of the eighth bell.

Now, if anyone wishes to have a larger or smaller octave, let him transfer the whole system AB to both sides of a divider, as they call it, as appears here; its use is as
follows. Intercept with the compass the largest diameter that you desire for some bell between the sides or legs AA. And then, without moving the instrument, the space CC will give the diameter of the second bell, the space DD the diameter of the third, and so with the other intervals in order, to II, which will give the diameter of the eighth bell. Through this endeavor, in the easiest way of all, given the diameter of the largest bell, of any size, you will obtain the diameters of all the rest. Since the ratios of all of these have been demonstrated in "The Division of the Monochord",161 we will spare the reader a repetition of them.

Problem II

To Determine the Proportions of Bells from their Thickness

The same method and the same rules may serve for investigating the proportion of bells for their thickness, as for their diameter. Therefore, if one divides the thickness (which, as I have indicated above, occupies that zone and region that the hammer strikes) of any largest bell into ten equal parts, nine of them will give the thickness of the second bell, and it will sound a minor tone above the first. The third bell, giving a major third below, will have a thickness a fourth larger than the first, and the fourth

161. Book IV of Musurgia.
bell, which sounds a fourth below the first, will be a third larger in thickness than the first. Then the fifth bell, sounding the fifth, will be three fifths larger than the first. Proceed in just the same manner with the rest of the bells in order. But so that, given the thickness of a bell, you may know the weight, and vice versa, given the weight you may know the thickness of any bell, we will prescribe the rules for you.

Rule I

Given the Thickness of Two Bells a Major Tone Apart, and the Weight of the Smaller, to Find the Weight of Any Other

Triple the ratio of a major tone, which is 9:8, i.e., cube these numbers, and you will get 729:512. Then let the smaller cube be to the larger as the smaller weight to the other, and you will get the desired weight of the second or larger bell. E.g., let the weight of the smaller bell be twenty-five pounds, and the smaller cube 512, the larger 729, and the example will stand as follows:

The cube 512 is to the cube 729 as 25 pounds is to what weight? 35 305/512 pounds will be the weight of the

162. After the second bell, Kircher starts proceeding downward from the first for the rest of his intervals. His original intention had undoubtedly been to continue decreasing the size of the bells, and raising their pitches. The fifth bell should be one half larger than the first; one three fifths larger would sound the sixth below.
second. The weight of a bell which sounds the octave of another will be had if you cube the ratio 1:2 of the octave; the cubes of both will be 1 and 8. Then assume as before that the first bell is or 25 pounds. This done, the example will stand, according to the rule of proportions, as follows:

1 is to 8 as 25 pounds is to what? 200, the weight of a bell sounding an octave below. Proceed in just the same way in finding the proportions and weights of all the other bells.

Rule II

Given the Thickness of the Edge of a Bell Weighing 200 Pounds, to Find the Thickness of Another Bell

In the preceding it has been shown how the thickness of the edge of any bell is the measure of all the rest of the proportions of the bell. And so if there were a bell that weighed 200 pounds and had a thickness of three inches, if there is sought a bell twelve inches thick, how many pounds will it weigh?

First, let the values of the thickness of each bell, 3 and 12, be cubed, and the result is 27 and 1728; and let it be that 27 inches are to 200 pounds as 1728 inches to the answer. The answer will be 12,800 pounds for a bell whose edge has a thickness of twelve inches. \(^{163}\) Proceed in

---

163. Kircher's very careless arithmetic has been corrected.
just the same way with all
the others.

Accordingly,
artisans of greater talent
keep a parallelepiped a half
foot long, on which they
designate in order the
thickness and weight of
bells, as follows: LM indi-
cates the thickness of the
first bell of twenty-five
pounds; NO indicates the
thickness of the second bell
of thirty pounds, PQ the
third, RS the fourth, and so
it is to be established with
the rest in the order the
Roman numerals indicate.
Thus XXIII indicates the
value of the thickness of a
bell weighing 15,534 pounds. Therefore you see that, just as
the smallest weighs twenty-five pounds with the thickness LM,
so the largest, weighing 22,276 pounds, has a thickness of
XXIV inches, about the largest that is cast at this time.
But since this artisans' scale is intricate, we will be doing something worthwhile if we transfer it to one line. Therefore do thus: Transfer to either side AC or FD of the present scale CDAF the values of the thickness of the bells following in order; i.e., transfer LI, the thickness of a bell weighing twenty-five pounds, from A to B and from F to E, and if a line BE is drawn, the space AB or EF will give you the thickness of the first bell. Then from the same points A and F, transfer the space NO of the second bell weighing thirty pounds, and, drawing a parallel line, you will have the thickness of the second bell at the second line parallel to BE. In just the same

164. He means the distance R-XXIV. The weights in the figure are copied with many mistakes from Mersenne.
draw the rest of the spaces according to the numbers of
the scale following each other in natural order, until you
have made a scale of twenty-four steps, each one of which
denotes the thickness of a bell weighing as many pounds as
the numerals written by it. E.g., CA or DF is the thickness
of a bell weighing 22,276 pounds. But these things are too
easy to need further explanation.

Problem I

Given the Thickness, to Find the Diameter of any Bell, or
What is the Same, its Width and Height

Since from the premises the thickness of any bell
is one fifteenth of the diameter and one twelfth of the
height,165 this thickness, transferred fifteen times to a
straight line representing the diameter or axis of the bell,
will give what was sought. E.g., IL, the thickness of a bell
weighing twenty-five pounds, transferred fifteen times to a
line, will give the diameter or width of the bell. The same
transferred twelve times to the axis will give the height.
Or, having the diameter or thickness, you will arrive easily
by means of the preceding at the value of the weight. The
same is to be established for the rest of the intervals.

165. On p. 143 the ratio of diameter to thickness used by
Italian founders is given as thirteen to one, and of height
to thickness fourteen to one.
Problem II

To Find the Difference in Pitch of Bells Equal in Size, but Made of Different Metals

Mersenne has shown us an experiment on this problem first in his Harmonie, and we also have made an experiment on this problem, but we found different pitches, so let us give the observations of both, so that the reason for the difference may become known. First of all a little bell of rather heavy metal must be made, and all the others, of various metals, made equal to it in all manners and in everything. And a careful workman will find a remarkable diversity, and will be compelled to assert that it is hardly possible, even if the experiment were repeated over a thousand times, that they would ever give precisely the same pitch. For even if two little bells are prepared of the same material, I have always noted something different in them, and that they are by no means identical in pitch. I have found that the reason for this fact is none other than the unequal flow of the material, spreading itself around unequally through the body of the bell; in consequence of this there is a diversity in the pitch. For since, as was shown in Book I, rarity and density are the causes of high and low pitch, certainly the air, when beaten by a rarer material, will give a much higher sound than when a dense material was struck, so that in consequence I would think that hardly anything could be
established as certain in this business. If all the materials were perfectly homogeneous there would be no doubt about the truth of the assertion made by Mersenne. But so that the truth of what has been said may be more clearly revealed, I have seen fit to include both observations here. 166

When these experiments had been observed according to Mersenne's ruler, with the very greatest effort, we finally observed these tones, employing Roman musicians esteemed for the greatest judgement of their ears. But whatever I would do, I could not perceive the same ones that Mersenne established. Consequently, I would like to make more observations of this thing, so that finally the cause of the error may be detected. Certainly, in this most uncertain business, endless and by no means circumstantial observations would have to be made in order to search out an exact knowledge of

<table>
<thead>
<tr>
<th>Material of bell</th>
<th>Mersenne</th>
<th>Kircher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin</td>
<td>e'</td>
<td>e'</td>
</tr>
<tr>
<td>Silver</td>
<td>f'</td>
<td>f'</td>
</tr>
<tr>
<td>Pure tin</td>
<td>f#'</td>
<td>g'</td>
</tr>
<tr>
<td>Mixed silver</td>
<td>g'</td>
<td>a'</td>
</tr>
<tr>
<td>Resonant tin</td>
<td>g#'</td>
<td>g#'</td>
</tr>
<tr>
<td>Tin and antimony</td>
<td>a#'</td>
<td>g'</td>
</tr>
<tr>
<td>Lead</td>
<td>b'</td>
<td>b'</td>
</tr>
<tr>
<td>Copper</td>
<td>c'</td>
<td>a'</td>
</tr>
<tr>
<td>Bell metal</td>
<td>c''</td>
<td>c''</td>
</tr>
<tr>
<td>Bismuth</td>
<td>d'</td>
<td>c''</td>
</tr>
<tr>
<td>Brass</td>
<td>e'</td>
<td>b'</td>
</tr>
<tr>
<td>Gold</td>
<td>e''</td>
<td>d''</td>
</tr>
</tbody>
</table>

166. For simplicity, the names of the notes have been given here, instead of presenting them on a staff, as in the original. It is not clear what metals are meant in some cases. Several values have been corrected on the basis of Mersenne's table.
the matter. For unequal pouring, unequal quality of the metals, the method of casting, the atmospheric conditions, a mixture of things, can result in much alteration of pitch even in equal bodies. Therefore, since a decision would be difficult to make, let us leave this matter and turn our pen to others.

Chapter III

The Drum, Cymbals, and other Composite Instruments

The drum is an instrument known to all, of sheep or ram skin and oak boards wrapped into the shape of a cylinder, as it appears in the figure, on both ends of which said skin is stretched with ropes. This alone among the skins of the other animals is manageable and fit for musical tone, so that just one little sheep feeds us, clothes us, and entertains us with four types of musical instruments, with intestines for strings, with shinbones and horns for pipes, and finally the skin turning into a drum, so that consequently the Hebrews have declared of it not inelegantly that the live animal has one voice; dead, seven. For two horns, two shinbones, the intestines, and skin are brought to life in as many instruments.

Furthermore, drums are constructed harmonically, in just the same manner as bells, provided that the ratios or
proportions of the intervals are exactly observed, so that if one wishes to adapt four drums so that the largest or first sounds a major third below the second, the second a minor third below the third, and this a fifth above the first, and finally the third to the fourth a fourth, and the fourth an octave to the first, their proportion to each other is as the numbers marked on the drums. 167

Therefore, if one would make four drums, whose heights and widths have the same ratios as the numbers four, 167. The numbers on the drums indicate vibration ratios, and consequently are in inverse proportion to size.
The proportion of drums necessary for making consonance.

five, six, and eight have, of which four to five gives the major third, five to six the minor third, six to eight the fourth, eight to four the octave, he would establish their height and width according to said numbers. E.g., if the first drum had thirty inches for its height, the second must have twenty-four inches for its height, the third twenty, and the fourth fifteen inches of height. The same is to be observed of the width, for drums mostly have the same height as width. There are other types of drums besides, but because these are of little service to music, we have omitted them.

In this place I cannot omit an instrument which sailors and soldiers use widely, called in the German language ein maultrummen,168 i.e., a mouth drum, because when inserted in the mouth it gives forth sounds. It is made of a steel sheet twisted almost into an oval figure, with a steel plectrum. This, placed in the hollow of the mouth, with the finger plucking the plectrum, gives rise to a sort of buzzing somewhat indistinct, but not unpleasing, and indeed harmonious. But since the nature of the instrument is clear of itself, we will waste time if we linger longer over it. Whoever desires more of this sort of thing should go to the "Musical Mechanics" and the treatise on the division of

168. The Jews' harp.
There is also another instrument which we call castanets, the Italians *gnaccari*. They are customarily used in conjunction with the sound of the guitar, beating the time established for the melody. I have omitted a picture of the instrument.

In this place nothing else seems to be required, except for us to pursue the musical instruments of all kinds used in all parts of the world. But since the increase neither of time, by a lack of which we are pressed, nor of labor would permit it, we have decided advisedly to omit them, especially since, if you except a few, they have mostly a great affinity with ours, and can be reduced to them in some way. Whoever desires more of this sort, let him consult writers on matters of India and other nations, in whom he will find whatever he may desire treated thoroughly.

These things are what I have seen fit to say about instrumental music. Unless I am deceived, the careful reader will find in this book whatever can be desired on the origin, nature, properties, constitution, and manufacture of musical instruments. He will see what and what sort of harmonies can be ingeniously applied to each instrument through appropriate

169. It is not clear whether these refer to other books of *Musurgia*; none of them have such titles.
compositions. And if they find favor in the ears of the hearer, I would wish that to be ascribed not to me, but to God the governor of all good things. Nothing remains for us therefore but to begin Book VII, in which whatever has been omitted in the preceding will be treated fully. But let us omit wordy digressions and attack the matter itself.
APPENDIX A

Incipits of the Main Sections of the Allegri Ensemble for Viols, p. 71
APPENDIX B

List of Names of Musical Instruments and Parts in Musurgia, with their Translations

Seventeenth-century French, Italian, and German words have been omitted, except those that Kircher commonly Latinizes. A question mark indicates a meaning which is not certain. The terms applying to the organ have been placed in a separate list after the main one.

<table>
<thead>
<tr>
<th>Term</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>abacus</td>
<td>keyboard</td>
</tr>
<tr>
<td>abacus harmonicus</td>
<td>keyboard</td>
</tr>
<tr>
<td>abacus manuarius</td>
<td>keyboard</td>
</tr>
<tr>
<td>abacus polyplectrus</td>
<td>keyboard</td>
</tr>
<tr>
<td>ansa</td>
<td>ear (of a bell)</td>
</tr>
<tr>
<td>archicymbalum</td>
<td>archicembalo</td>
</tr>
<tr>
<td>arcus</td>
<td>bow</td>
</tr>
<tr>
<td>campana</td>
<td>bell</td>
</tr>
<tr>
<td>canon</td>
<td>fingerboard, neck?</td>
</tr>
<tr>
<td>chelys</td>
<td>viol</td>
</tr>
<tr>
<td>chelys hexachorda</td>
<td>viola da gamba</td>
</tr>
<tr>
<td>chelys minor</td>
<td>violin (or viola)</td>
</tr>
<tr>
<td>choraulos</td>
<td>dolcian, bassoon</td>
</tr>
<tr>
<td>chorda</td>
<td>string</td>
</tr>
<tr>
<td>clarina</td>
<td>clarino</td>
</tr>
<tr>
<td>claviarium</td>
<td>keyboard</td>
</tr>
<tr>
<td>clavichordium</td>
<td>clavichord</td>
</tr>
<tr>
<td>clavicymbalum</td>
<td>harpsichord</td>
</tr>
<tr>
<td>collum</td>
<td>neck, pegbox, fingerboard?</td>
</tr>
<tr>
<td>cornamusa</td>
<td>bagpipe</td>
</tr>
<tr>
<td>cornu</td>
<td>horn, cornett</td>
</tr>
<tr>
<td>cornu venatorum</td>
<td>hunting horn</td>
</tr>
<tr>
<td>crepitaculum</td>
<td>castanets</td>
</tr>
<tr>
<td>cymbalum</td>
<td>cymbals</td>
</tr>
<tr>
<td>cythara</td>
<td>cittern, guitar</td>
</tr>
<tr>
<td>dorsum</td>
<td>back (of a stringed instrument)</td>
</tr>
<tr>
<td>dulcinum</td>
<td>dolcian, bassoon</td>
</tr>
<tr>
<td>fagotus, fagottus</td>
<td>bassoon</td>
</tr>
<tr>
<td>fistula</td>
<td>pipe, flute</td>
</tr>
<tr>
<td>fistula enneastoma</td>
<td>recorder</td>
</tr>
<tr>
<td>fistula hexastoma</td>
<td>flageolet</td>
</tr>
<tr>
<td>fistula militaris</td>
<td>fife</td>
</tr>
<tr>
<td>fistula tristoma</td>
<td>galoubet</td>
</tr>
<tr>
<td>harpa</td>
<td>harp</td>
</tr>
<tr>
<td>hyposalpinx</td>
<td>trombone slide</td>
</tr>
<tr>
<td>instrumentum crustum</td>
<td>percussion instrument</td>
</tr>
</tbody>
</table>
instrumentum pneumaticum  wind instrument
instrumentum polychordum  stringed instrument
instrumentum pulsatile  percussion instrument
ligatura  fret
lingua  clapper
lingula  tongue (of a harpsichord jack), mouthpiece
linterculus  kit
lituus  cromorne
lyra dodecachorda  *lirone, lira da gamba*
lyra germanica  hurdy-gurdy
lyra vulgaris  hurdy-gurdy
lyra mendicorum  hurdy-gurdy
magadis  bridge?
malleolus  tuning hammer
malleus  clapper
mandora  mandora
manubrium  fingerboard, neck
manuchordium  clavichord
monochordon  monochord, marine trumpet
musetta  musette
nola  small bell
organum  organ, instrument
palmula  key
pandora  pandora
plectrum  plectrum, bow?
psalterium  psaltery
regalium  regal
registrum  stop, draw-stop
serpens  serpent
spinetta, spinettum  spinet
subsilium  jack
systema campanarum  carillon
tastatura  keyboard
testudo  lute
testudo bijuga  theorbo
testudo compendiata  mandora
theorba, thiorba, tiorba  theorbo
tibia  flute, cornett
tintinnabulum  small bell
tuba  trumpet
tuba ductilis  trombone
tympanum  drum
utriculus  bagpipe
venter  belly
verticilla  peg
viola  viol
zylorganum  keyed xylophone
## Organ Terms

<table>
<thead>
<tr>
<th>Latin Term</th>
<th>English Term</th>
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</thead>
<tbody>
<tr>
<td>ala</td>
<td>ear</td>
</tr>
<tr>
<td>anemotheca</td>
<td>wind trunk, wind chest</td>
</tr>
<tr>
<td>anthropoglossa</td>
<td>vox humana</td>
</tr>
<tr>
<td>aulotonus</td>
<td>tuning wire</td>
</tr>
<tr>
<td>auricula</td>
<td>ear</td>
</tr>
<tr>
<td>canalis ventorum</td>
<td>wind trunk</td>
</tr>
<tr>
<td>canon</td>
<td>register</td>
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<tr>
<td>choraulos</td>
<td>dulciana</td>
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<td>cribrum</td>
<td>table</td>
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<tr>
<td>fistula</td>
<td>pipe, flue pipe</td>
</tr>
<tr>
<td>follis</td>
<td>bellows</td>
</tr>
<tr>
<td>lingua</td>
<td>tongue</td>
</tr>
<tr>
<td>lingula</td>
<td>lip, tongue</td>
</tr>
<tr>
<td>paraglossa</td>
<td>pallet</td>
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<tr>
<td>paraulos</td>
<td>chimney flute</td>
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<tr>
<td>pilotis</td>
<td>sticker</td>
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<tr>
<td>polystomaticum</td>
<td>sound board</td>
</tr>
<tr>
<td>registrum</td>
<td>register</td>
</tr>
<tr>
<td>secretum organicum</td>
<td>wind chest</td>
</tr>
<tr>
<td>secretum ventorum</td>
<td>wind chest</td>
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<tr>
<td>systema</td>
<td>register</td>
</tr>
<tr>
<td>zooglossa</td>
<td>reed pipe</td>
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</tbody>
</table>
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