THE EARLY CLAVICHORD[1]

By EDWIN M. RIPIN

The history of the clavichord may conveniently be divided into two periods. Our knowledge of the first of these periods is derived solely from written descriptions and pictorial representations; the second, which extends from the middle of the 16th century to the beginning of the 19th century, is almost completely documented by surviving instruments. The two periods are differentiated from each other by more than differences in methodology and source materials. It appears that the earliest surviving clavichords are representatives of a type quite new at the time they were built, and that their predecessors were unlike them in a number of ways. It is with the development of these earlier instruments in the century between 1440 and 1540 that this article will principally be concerned.

The earliest years of the clavichord's development are utterly obscured by an unfortunate terminological muddle. Clear through the 15th century, the term *monochordium* was applied to both the many-stringed keyboard instrument and the simple box with often only a single string and no keyboard used by the Greek theoreticians and their medieval successors in their researches into intervals and scales. The confusion is compounded by the fact that keyboardless monochords were used for music-making as well as for purposes of teaching and experimentation. Thus, the mention of a monochord in connection with musical performance does not necessarily point to the clavichord, and this is especially true for such early references as those in

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Wace's *Roman de Brut* (1157) or Guiraut de Calanson's *Conseils aux Jongler* (1210).

The first appearance of the word *clavichord* occurs in Eberhard Cersne's *Minne Regal* of 1404, but it is not until the middle years of the 15th century that we find descriptions of instruments explicitly called clavichords as well as pictures and carvings of instruments with keyboards. There are, in all, less than a dozen representations of clavichords dating from the 15th century, including a sculpture and a stained-glass window from England, a wood-carving and a painting from the Netherlands, several drawings and miniatures from France and Germany, and a fresco and an intarsia from Italy.[2] The 15th-century writings are even less numerous, but there are a few manuscript treatises that deal with the instrument,[3] of which by far the most

[2]These representations are listed below in approximate chronological order, together with a single readily available work in which each is reproduced. Several of the representations are, of course, reproduced elsewhere, for example by Edmund A. Bowles, *On the Origin of the Keyboard Mechanism in the Late Middle Ages*, in *Technology and Culture*, VII, 2 (Spring 1966) and Hanns Neupert, *The Clavichord*, Kassel, 1965.

1. Naples, San Giovanni a Carbonara (reproduced here as Plate 1).
2. Shrewsbury, St. Mary's Church (reproduced in Francis W. Galpin, *Old English Instruments of Music*, London, 1965, p. 91).
3. Arnaut of Zwolle (reproduced here as Fig. 1).
4. Warwick, St. Mary's Church, 1447 (reproduced in Frank Harrison and Joan Rimmer, *European Musical Instruments*, New York, 1964, Plate 77).
5. Coburg, Landesbibliothek MS Cas. 43, fol. III, Otto von Passau, *The Twenty-four Elders*, 1448 (reproduced in Georg Schünemann, *Die Musikinstrumente der 24 Alten*, in *Archiv für Musikforschung*, I [1936], 56).
6. Stuttgart, Württembergische Landesbibliothek, Cod. poet. et phil. Q 52, fol. 65v. (reproduced in Jacques Handschin, *Das Pedalklavier*, in *Zeitschrift für Musikwissenschaft*, XVII [1935], 420).
7. Amsterdam, Rijksmuseum, Adriaen van Wesel, *Three Music-Making Angels with Joseph*, 1475-77 (reproduced in Georg Kinsky, *Geschichte der Musik in Bildern*, Leipzig, 1929, p. 64).
8. Urbino, Palazzo Ducale (reproduced here as Plate 2).
9. Rotterdam, Boymans-van Beuningen Museum, Geertgen tot Sint Jans, *Glorification of the Virgin* (reproduced in Marc Pincherle, *An Illustrated History of Music*, New York, 1959, p. 30)

To this list one might add the drawing in the so-called *Weimar Wunderbuch* (Weimar, Thüringische Landesbibliothek, MS "fol. 120v," fol. 328) sometimes referred to as the earliest surviving representation of a clavichord and reproduced as such in *Die Musik in Geschichte und Gegenwart*, II, 1467-68. The ascription of this drawing to the 15th century is, however, highly questionable.

[3]These generally give little more than instructions for determining the proportions of the sounding lengths of the strings. Typical are the sets of instructions in Erlangen University Library MS 554 (one of which is transcribed in part by Wilhelm Dupont, *Geschichte der musikalischen Temperatur*, Kassel, 1935, pp. 20-21), those in Geneva MS lat. 80 (transcribed by Jacques Handschin, *Aus der alten Musiktheorie*, in *Acta Musicologica*, XVI-XVII [1944-45], 4-9), and that in Yale University Medical Library MS. De Ricci 25. There is, in addition, a short description of the instrument in the *Liber XX artium* of Paulus Paulirinus of Prague, written

important is that by Arnaut of Zwolle, which dates from about 1440.[4]

The representation reproduced in Plate 1 is a portion of a fresco in the Caracciolo Chapel of San Giovanni a Carbonara in Naples. It may well be the earliest surviving representation of the instrument, since it probably was painted before 1435.[5] Although the painting is a trifle crude, the most characteristic features of the clavichord are visible. The instrument is essentially a rectangular box, with the keyboard projecting from one of the longer sides. The entire center and left-hand portions of the case are occupied by the keys, which pass beneath the strings, running at right hand angles to them. (The soundboard, which occupies the right-hand end of the instrument, is, unfortunately, largely obscured by the near end of the case.) A particularly interesting detail of this instrument is the lack of sidepieces of any kind on the keyboard. Their absence seems to be universal in rectangular stringed keyboard instruments down to Virdung's time, although the keyboards of all the surviving 16th-century instruments do have sidepieces.

Arnaut's treatise differs from any of the other manuscripts in presenting diagrams in addition to directions for determining proportional string lengths. The first of his clavichord diagrams (Fig. 1) is labeled *compositio clavicordii* and shows the layout of an instrument with a three-octave keyboard. The bent lines within the case indicate the centers of the keys, and the distances from these lines to the bridge (labeled *stephanus* on the diagram) correspond precisely to the proportions Arnaut gives for the sounding lengths of the strings. This makes it clear that Arnaut's layout as a whole was drawn to scale, which, in turn, enables us to make a fair guess at the actual dimensions of the instrument from the widths of the keys. These dimensions work out to be approximately 33 inches long, 8½ inches from front to back, and 4 inches high.[6]

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about 1460. (Transcribed by Josef Reiss, *Pauli Paulirini Tractatus de Musica,* in *Zeitschrift für Musikwissenchaft,* VII [1924-25], 262; also available in English translation in Susi Jeans, *The Pedal Clavichord and Other Practice Instruments of Organists,* in *Proceedings of the Royal Musical Association,* LXXVII [1950-51], 2, 14.)

[4]Bibliothèque Nationale MS lat. 7295. Facsimile with transcription, translation, and notes by G. Le Cerf and E.-R. Labande, *Instruments de musique du XVe siècle,* Paris, 1932.

[5]The author is indebted to Dr. Colin Eisler of the New York University Institute of Fine Arts for dating this fresco and the painting reproduced in Plate 4.

[6]These dimensions are somewhat larger than those suggested by Cecil Clutton, *Arnault's MS,*

In Fig. 1, the sounding lengths of the strings for the four B's are indicated above Arnaut's layout. The sounding length for *b'* is twice that for *b''*, and it goes on doubling for each octave.[7] As a result, the sounding length of the string for the low *B* is fully eight times as great as that for the high *b''* three octaves above. This is, of course, exactly the relationship that would be found if the instrument had only a single string, and it is this characteristic of the early clavichord that explains how these instruments could be referred to as monochords. Arnaut's clavichord actually had at least nine pairs of strings (as stated in his text and indicated by the tuning pins shown at the right-hand end of his layout diagram), and the fact that his many-stringed instrument is laid out as if it had only a single string tells us that all its strings must have been tuned in unison.

At this point, one might well wonder why, if all the strings of a clavichord were to be tuned in unison, one should bother with more than just one string or perhaps a close-set pair for increased loudness. The reason for having more than one string is that the clavichord tangent serves two functions: in addition to setting the string into vibration when its key is depressed, the tangent divides the string into two parts, one of which is damped with cloth while the other is allowed to sound. The point at which the tangent strikes the string determines the length of this sounding portion and consequently determines the pitch that the string produces. For this reason, a number of tangents striking a string at different points produce an equal number of different pitches. This, in turn, makes it possible to build an instrument with only a single string, like that described by Conrad von

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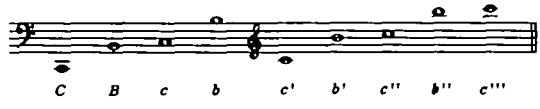
in *Galpin Society Journal,* V (1952), 6, or employed by Hanns Neupert, in his model of the instrument (Musikhistorisches Museum Neupert, Bamberg), both of whom assume octave spans rather narrower than this writer feels to be justified by the available evidence, especially the 7-inch octave of the Urbino intarsia shown in Plate 2. The height of the case is derived from Arnaut's statement that it should be half the width (see footnote 26).

[7] The designations of pitches used in this article, unlike those used by Arnaut, change at C:



Throughout, italic capital letters refer specifically to the notes of the octave above low *C*. Roman capitals refer to notes the register of which need not be specified.

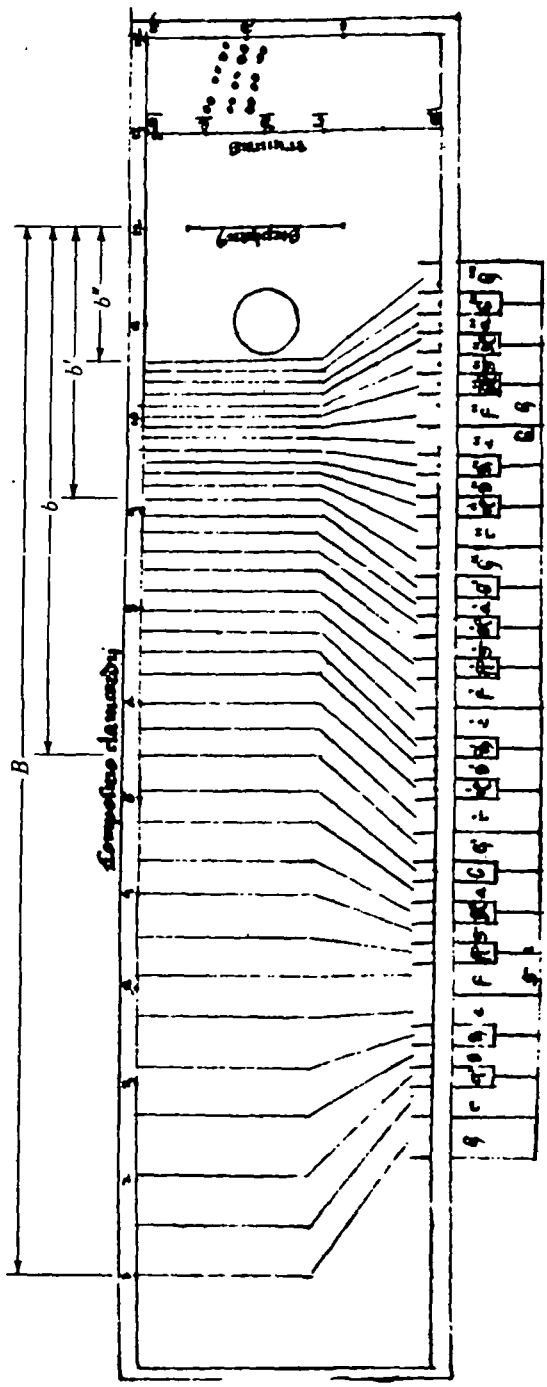


Fig. 1. Arnaut of Zwolle's Clavichord Layout (From Bibliothèque Nationale MS lat. 7295, fol. 129.)

Zabern in 1470,[8] provided that the keys are so arranged that their tangents strike the string at the proper places. There is one hitch to all this, however. A string can have only one sounding length at a time and can produce only one note at a time; thus, the true clavichord (in the sense of an instrument on which, as on other keyboard instruments, one can play polyphony and chords) must always have more than a single string. The eight-string "monochord" described by Giorgio Anselmi in 1434[9] clearly meets this demand, whereas von Zabern's (although it might conceivably have been used to sound melodies lying within its Guidonian *G—e'* compass) does not.[10]

Since each string in a clavichord can only sound one note at a time, the ability to play a chord on the instrument depends on having a separate string for each of the chord's notes. Sebastian Virdung in his *Musica getutscht* of 1511 makes this quite clear when he states that a clavichord must have more than one string if one is to be able to play simultaneous consonances.[11] Virdung later says that each close-set choir of two or three strings is generally struck by three tangents.[12] The first of these statements does more than merely tell us why a clavichord must have more than one string. It explains the rationale behind the way in which the tangents of early clavichords were arranged; and the arrangement of tangents, in turn, provides one of the threads that permit us to understand the development of the clavichord during the period that precedes the earliest surviving examples.

If all possible consonances are to be sounded, no two of the tangents striking a given choir of strings can belong to keys that would sound a consonance with each other. This explains why "for the most part" *(das merer teyl)* the strings were struck by three tangents each.

[8]See Karl-Werner Gümpel, *Das Tastenmonochord Conrads von Zabern*, in *Archiv für Musikwissenschaft*, XII (1955), 143-66.

[9]See Walter Nef, *The Polychord*, in *Galpin Society Journal*, IV (1951), 23.

[10]Unlike the portative organ, which could be used to play a single melody in ensemble with other instruments, the softness of the sound produced by a tangent striking a string would make the single-string clavichord useless for this purpose unless one plucked the string with one hand while manipulating the keys with the other. If this was, in fact, the way in which such instruments were used, they might be regarded as some kind of link between the hurdy-gurdy, in which the strings are stopped by tangent-like points while being bowed by a rosined wheel, and the true clavichord, in which the tangent sets the string into vibration in addition to measuring off its sounding length.

[11]"Dann man vff einer saiten alleyn simul et semel oder gleich mit eynander kein consonantz machen mag clingen . . . " Fol. E iii.

[12]"Aber gmainlich mcht man drey saiten vff einem kor . . . das merer teyl auch der koere / hat ietlicher dry schlüssel die in anreichen oder anschlagen." Fol. F.

Considering any three consecutive keys — for example C, C♯, and D — it is clear that the only intervals between these notes are dissonances, namely major and minor seconds. If one attempts to have four tangents striking a single choir, for example those for C, C♯, D, and E♭, one can lose a consonance, here the minor third C — E♭. That is, if the tangents for C and E♭ both strike the same choir of strings and one attempts to play the two notes simultaneously, only the E♭ will sound. If one takes a different group of four tangents, however, a different result may be obtained. Consider the four tangents for E♭, E, F, and F♯. Here the interval between the outermost members of the group is an augmented second rather than a minor third, and having these four tangents striking a single choir would not interfere with the playing of any consonant chord.[13] Similar reasoning yields the result that the four tangents for F, F♯, G, and G♯ or B♭, B, C, and C♯ might also be permitted to strike a single set of strings. If one arranges five tangents so that they will all strike a single choir, the interval between the outer two keys will usually be a major third; in addition, at least one minor third (and often two) will become unplayable. Accordingly, having five tangents striking a single choir will invariably result in making it impossible to play at least one consonant chord. Thus, if Virdung's statements have been correctly interpreted, one should expect early clavichords to have their tangents arranged in groups of four and three, the groups of four filling the interval of an augmented second and the groups of three occurring where the addition of the fourth tangent would create the interval of a minor third between the outermost keys.[14]

With this idea in mind, we can return to Arnaut of Zwolle. Fig. 2 reproduces Arnaut's schematic representation of the arrangement of

[13] The crucial assumption here is that the E♭ is not to be thought of as a D♯ or the F♯ as a G♭. This assumption appears to be completely justified by tuning manuals and other 15th- and 16th-century writings. (The accidentals on early keyboard instruments were almost invariably considered to be C♯, E♭, F♯, G♯, and B♭ rather than their enharmonic equivalents.

[14] In a rather obscure sentence immediately following that quoted in note 12, Virdung states: "Begeben sich nymer zwen zu eynenmal zu schlagen dann die gmainlich dissonirn." Jacob Eisenberg, *Virdung's Keyboard Illustrations,* in *Galpin Society Journal,* XV (1962), 83, translated the two sentences: "Each string is served by at least three keys but only those two keys (tones) can *not* be struck (sounded) together which will be dissonant," a reading that would provide substantial confirmation of this hypothesis. Unfortunately, Virdung's second sentence merely seems to be saying that the simultaneous striking of two keys that sound the same string produces a nonmusical noise, and he would appear to be cautioning the student rather than enunciating a principle of clavichord design.

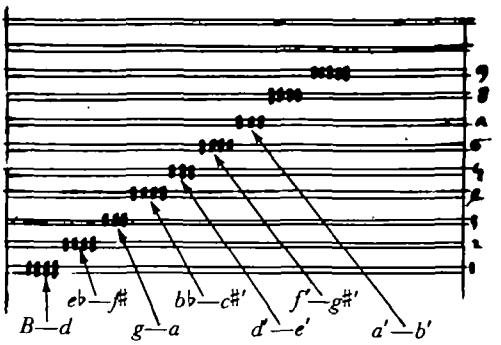


Fig. 2. Arnaut of Zwolle's Tangent Diagram (From Bibliothèque Nationale MS lat. 7295, fol. 129v.)

tangents in his clavichord. The pairs of strings are indicated by the numbered pairs of horizontal lines and the tangents by the vertical strokes. The tangents are all arranged in fours and threes except for those of the topmost numbered pair of strings, which is struck by five tangents. The lowest pair of strings is struck by the tangents for the four semitones of the minor third *B* — *d*, and the five tangents striking the topmost string sound all the notes in the major third $g'' - b''$. Thus, both of these sets of strings clearly contradict the principle that has just been so laboriously derived from Virdung. However, considering the remainder of the instrument, the principle does appear to explain the arrangement of fours and threes. The four tangents of the second pair of strings sound *e*♭, *e*, *f*, and *f*♯, the outer notes of which form an augmented second, not a minor third. The third pair of strings is struck by the three tangents for *g*, *g*♯, and *a*; and a fourth tangent could not be added here because the next note, *b*♭, would form a minor third with *g*, the lowest note of the group. The four tangents striking the fourth pair of strings, *b*♭, *b*, *c′*, and *c*♯′, again encompass only the interval of an augmented second. The three tangents of the fifth string sound *d′*, *e*♭′, and *e′*; here, as on the third string, a fourth tangent cannot be added because it would form a minor third with the lowest note of the group. The sixth string is struck by the four tangents for *f′*, *f*♯′, *g′*, and *g*♯′, which comprise yet another augmented second, and the seventh string is served by the three tangents for *a′*, *b*♭′, and *b′*.

At this point, there are only nine tangents left on Arnaut's diagram, and an entire octave of twelve keys remains of the range

shown on the layout drawing (Fig. 1). Clearly, there is an error of some kind in the smaller diagram, and a moment's thought will reveal that, if the 37 tangents of a three-octave instrument are to be distributed among only nine pairs of strings, each pair would have to be struck by four tangents, except for one pair that would have to be struck by five. Since the third, fifth, and seventh pairs of strings on Arnaut's diagram are struck by only three tangents each, it is easy to see how the number of tangents indicated on the diagram totals to 34 instead of the required 37. It is possible that Arnaut simply omitted a fourth stroke from each of these three groups, but this seems highly unlikely. The visual consistency of a series of identical groups of four terminating in a single group of five is such that it is hard to imagine that even a single omitted stroke, much less three of them, would not have been immediately obvious to Arnaut as he was drawing the diagram. In fact, if a uniform series of fours was what he intended, it is difficult to see why he would have drawn the diagram at all when it would have been so much simpler merely to write the words "each pair of strings has four tangents except the last, which has five." Finally, the correspondence of the pattern of fours and threes with that implied by Virdung's statement of seventy years later can hardly be a mere coincidence.

For all these reasons, it seems probable that the mistake that Arnaut made was to omit one pair of strings entirely, and with it the three tangents that such a pair would have carried.[15] If this is indeed the case, the omitted pair of strings would logically follow the seventh pair shown on Arnaut's diagram. The first column of the table on page 537 shows the tangent arrangement of Arnaut's clavichord with the choirs separated by horizontal rules. As may be seen, the added pair of

[15]It must be stressed that Arnaut is completely consistent in indicating nine pairs of strings in his text and in both diagrams. The explanation for the discrepancy between the nine pairs he shows and the ten pairs that 37 keys require may lie in the fact that Arnaut's layout directions did not originate with him. This section of his treatise (fol. 128 v.) is headed "Compositio clavicordiorum secundum librum Baudeceti," and it is possible that the otherwise unknown Baudequet gave directions for a nine-pair instrument of a smaller range than Arnaut's. The directions give specific instructions only for the notes up to *f″*, and nine pairs of strings would fit this range perfectly. Supporting this suggestion is the fact that a *B—f″* range seems to have been common in 15th-century clavichords. It is, for example, the range of the instruments described in Erlangen University Library MS 554 and of the pedal clavichord listed as number 6 in footnote 2. On the other hand, Arnaut is not above a simple numerical slip. In concluding the instructions for laying out the clavichord, he refers to the instrument's "35 tonos," although his diagram clearly shows that it had 37 keys. (Arnaut was probably thinking here of the keyboard of his harpsichord shown on the preceding page, which had only a 35-note range, *B—a″*.)

Plate 1
Celestial Concert from *Lives of the Hermit Saints* by Perrinetto da Benevento in the Caracciolo Chapel of San Giovanni a Carbonara, Naples

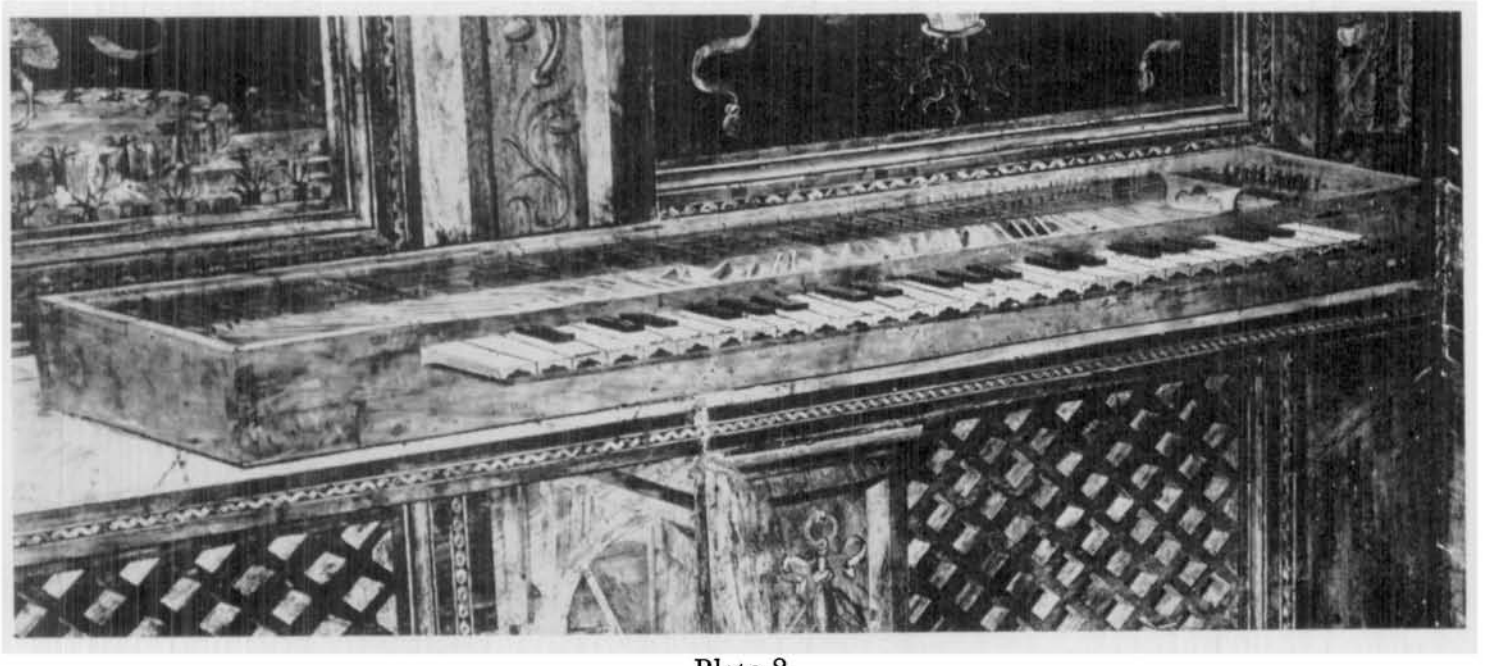


Plate 2
Intarsia of a clavichord from the Studiolo of Federigo da Montefeltro, Palazzo Ducale, Urbino

Plate 3
Woman Playing the Clavichord by Jan van Hemessen (Worcester Art Museum)

Plate 4
Woman with a Clavichord by a follower of the Master of the Female Halflength (Washington, D.C., private collection)

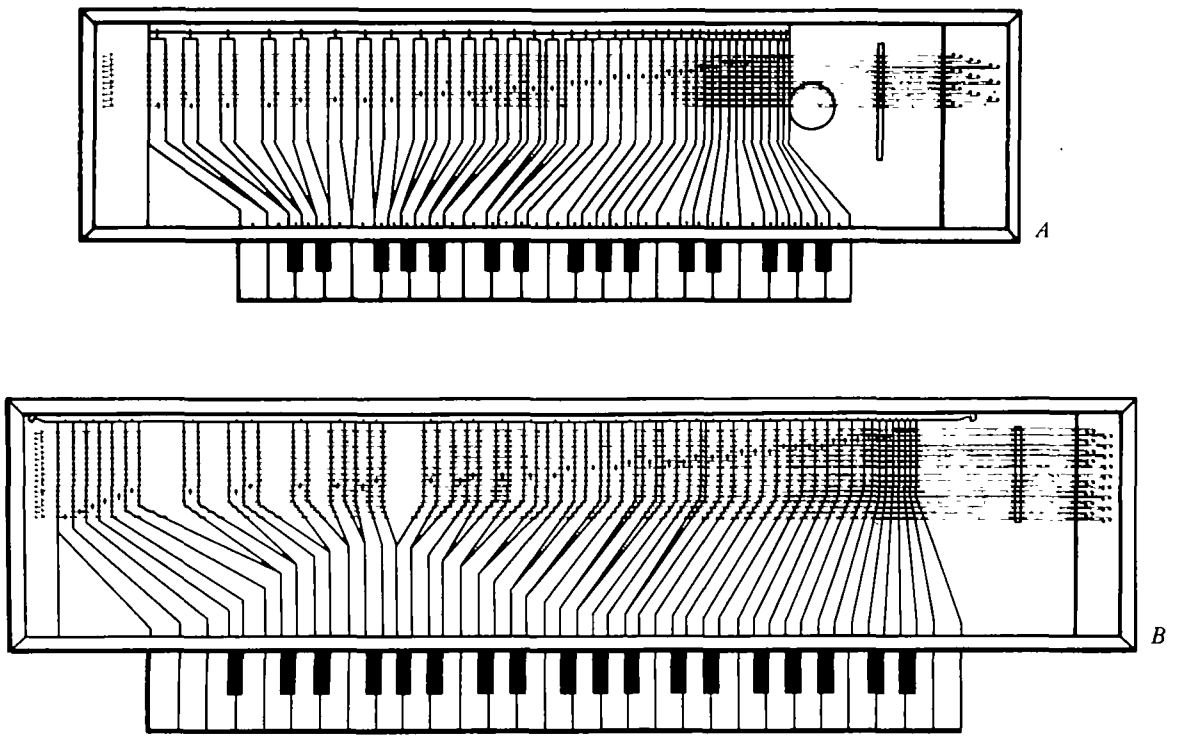
strings would serve the tangents for c'', $c\sharp''$, and d''. The four tangents of Arnaut's next-to-last pair would then sound the notes of a final augmented second, $e\flat''$ to $f\sharp''$, and his highest string the remaining notes g'' to b''. The present writer's reconstruction of the instrument, including the added choir of strings, is shown in Fig. 3A.

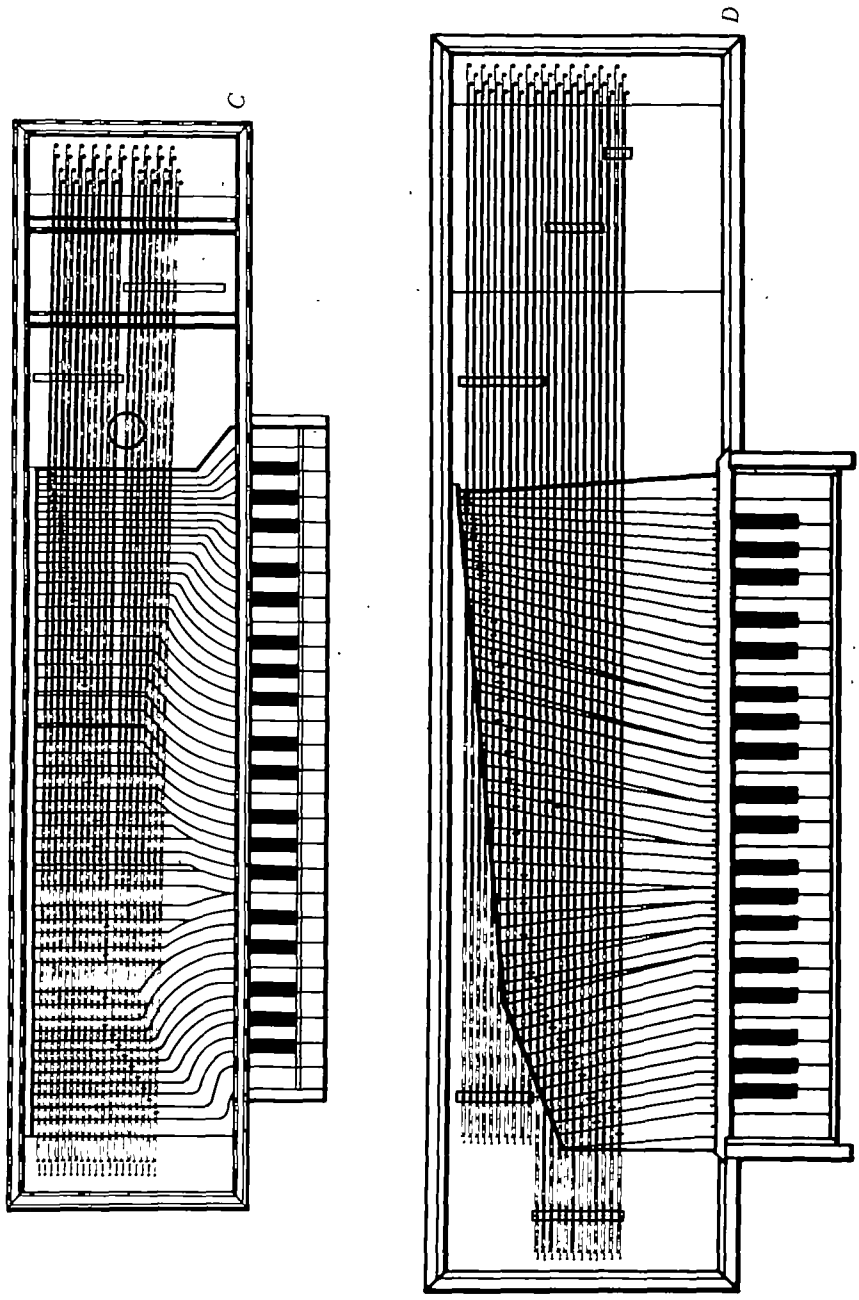
Before leaving the clavichord of the mid-15th century, one must consider the question of why and how instruments of the kind of which Arnaut's appears to be typical came to be replaced by a type more like those familiar to us from surviving 16th-century examples. The characteristic that, more than any other, sets Arnaut's clavichord apart from any surviving instrument is that Arnaut's clavichord had all its strings tuned in unison. An instrument of this kind possesses an enormous disadvantage inherent in the fact that its strings must double in length for each octave of its range. As is shown in Fig. 3A, the keys are bent to some fairly severe angles in order to bring the tangents under the proper points on the strings. If Arnaut had wished to increase the range of the instrument, this problem would have become even more acute. The range cannot be extended upward by cramming more keys into the treble, since the ends of these added keys would have to be even narrower than those shown, and therefore would be too weak to support the tangents driven into them. Thus, the only way to increase the range of an instrument like Arnaut's is by adding keys at the bass end, where the spreading of the keys is already so great that the addition of even a single semitone would increase the length of all the strings (and the over-all length of the instrument) by 1½ inches. Attempting to increase the range from three octaves to four would require doubling the vibrating length of the string sounding the lowest note, which would entail lengthening the instrument from 33 inches to nearly 60 inches, while the length of the keyboard would increase by only 7 inches. The resulting bending of the keys would be so severe as to make the instrument wholly unplayable. This fact makes it highly probable that the abandonment of the all-strings-in-unison design was primarily a consequence of the impossibility of building such instruments with a range much greater than three octaves. Virdung, who is the last writer to state that the strings of clavichords should all be tuned in unison,[16] gives a range of three

[16] ". . . aber daran ligt es alles / der saiten vff dem instrument synd vil oder wenig / so lug dz sye alle sampt ein vnisonum haben oder ein gliche stymm keine hoeher noch niderer dann dye ander." Fol. E iii.

Fig. 3. Layouts of Four Early Clavichords (one-seventh actual size)

A. Reconstruction of Arnaut's clavichord, c. 1440. *B*. Reconstruction of the clavichord of the Urbino intarsia, 1487-90. *C*. Anonymous clavichord, dated 1562, in the Musical Instrument Museum of the Karl-Marx-Universität, Leipzig. *D*. Clavichord by Onesto Tosi, Genoa, 1568, in the Museum of Fine Arts, Boston.




C
D

octaves and a whole tone as normal for clavichords,[17] and it is likely that this represents the maximum practical range for an instrument that had all its strings tuned in unison. When Virdung later mentions the existence of "newer" clavichords with a range of four octaves or more,[18] he is surely speaking of instruments of the type in which the strings were tuned to different pitches,[19] the first mention of which occurs in Ramos de Pareja's *Musica practica,* published in Bologna in 1482.[20]

If one considers the problems of expanding the range of Arnaut's instrument from three octaves to four, it is immediately apparent that the keys will always have to spread a good deal as one gets down into the bass in order to provide for the necessary 6%-per-semitone increase in string length between adjacent tangents striking the same string. But there is some spreading between the keys of Arnaut's design that serves no function at all and only exists because the strings of the instrument were tuned in unison. This needless spreading can be seen in Fig. 3A and occurs between adjacent keys that strike different strings (as between *d* and *e♭*, *f♯* and *g,* etc.). This spreading wastes at least two inches of the total length of Arnaut's instrument. Furthermore, if the strings are not tuned in unison, any increase in the sounding length of the highest string will not automatically appear multiplied sixteen-fold in the sounding length of the string four octaves below. This means that it would be possible to make the distance from the tangent for high *b‴* to the bridge somewhat greater, which, in turn, would make it possible to add a few more keys in the treble without having any with ends thinner than those on Arnaut's instrument.

[17] ". . . von dem vndristen schlüssel an zu rechnen biss zu dem obristen gerad . . . acht vnd dryssig schlüssel werden gefunden." Fol. E iiii. The diagrams on fols. Eiiii v. and G v. show that the 38 keys produced a range of *F—g‴* omitting *F♯*.

[18] ". . . vnd wye wol man ouch jetzunden vil nüwer clauicordia findet / die noch groesser oder lenger von fier octauen oder noch mer schlüssel haben." Fol. F.

[19] Virdung states that the strings of the larger clavichords were made of steel in the treble and brass in the bass. ("Dann der messing laut von natur grob vnd der stahel cleyn / vnd so man nun so vil als fier octauen / vnd noch mer daruff macht zu haben / so bezeucht man dye vndern kore mit den messenen / vnnd dye oberern mit den stehelin saiten." Fol. F v.) Strings intended to be tuned in unison would not be made of different materials.

[20] "Sunt etiam chordae diversae et in longitudine et in grossitie, ut in cithara et lyra, polychordo, clavichordo, clavicimbalo, psalterio et in aliis pluribus instrumentis . . ." Ed. J. Wolf, *Beihefte der Internationalen Musikgesellschaft,* II (1901), 15. Strings of different lengths and thicknesses, like those of different materials, would not be tuned in unison. Elsewhere, as pointed out by Nef, *op. cit.,* p. 22, Ramos refers to the clavichord with all its strings tuned in unison by the name *monochord.*

Naturally, more strings would have to be added to accommodate the added keys. This increase in the instrument's range would produce little or no increase in over-all length, since the added keys and string-length in the treble would hardly do more than take up the space wasted between the keys striking different strings. But one could scarcely hope to get more than halfway to the goal of four octaves by this means, and the bending of the keys in the bass would certainly not be reduced. Clearly, the best solution would be one that permitted the addition of bass keys that would have no spread between them at all. This is possible, of course, but only if each key added has its own pair of strings. Supposing that one wished at the same time to eliminate the exceptional situation of four tangents sounding all the notes from *B* to *d* on Arnaut's first pair of strings, one would also give low *B* its own pair of strings, which, incidentally, would close up the widest key gap on Arnaut's instrument. In this way, a substantial number of strings would have to be added, but one could achieve the desired expansion in range from three octaves to four without producing an unplayable instrument. However, it should be emphasized that this expansion would not be possible if all the strings are kept in unison.[21]

There exists a remarkable representation of a clavichord that documents the instrument at the completion of the process just described. Plate 2 shows an intarsia on a wall of the Studiolo of Federigo da Montefeltro in the Ducal Palace at Urbino. It was executed between 1479 and 1482, catching the clavichord just after the moment of transition from the all-strings-in-unison type and before the emergence of a still more efficient design in the 16th century. The special value of the Italian intarsias as documents in music history is well known[22] and lies in the photographic realism with which they depict objects in their actual sizes. The intarsia in Plate 2 is so detailed that it is possible to count the strings and determine the arrangement of the tangents on them. As shown in the second column of the table,

[21]Another approach to this problem is suggested by the fact that the sounding length of the string for the highest note will always have to be about the same length (regardless of what this note is called) if the key ends are not to get too thin. The entire process of extending the range of the instrument then becomes one of adding keys in the bass (saving what space one can between keys striking different strings) until the spread between adjacent keys striking the same string becomes so great that each key must be given its own string.

[22]Emanuel Winternitz, *Quattrocento-Intarsien als Quellen der Instrumentengeschichte*, in *Bericht über den siebenten Internationalen Musikwissenschaftlichen Kongress Köln 1958*, Kassel, 1958, pp. 300-02, and *Alcune rappresentazioni di antichi strumenti italiani a tastiera*, in *Collectanea Historiae Musicae* II (1956), 466-68.

this arrangement is identical to that worked out for Arnaut's instrument except for the bass and the extreme treble. In the bass each key from *F* to *B* has its own string, and in the treble Arnaut's group of five tangents for the interval *g″* to *b″* is broken up. The tangents for *g″*, *g♯″*, and *a″* form their own group, and those for *b♭″* and *b″* start a group of four reaching *c♯‴* on an added pair of strings. A second added pair is required for the notes *d‴* to *f‴*, which (like the topmost pair on Arnaut's instrument) is made to carry more than its fair load of tangents.

In order to clarify the changes between Arnaut's all-strings-in-unison clavichord and the Urbino instrument with its strings tuned to different pitches, the layout of the Urbino clavichord is shown in Fig. 3B[23] directly below that of Arnaut's. That the spread between keys that play on different strings has been eliminated is clearly visible, and it is easy to see how the bass keys, each with its own string, increase the range of the instrument without appreciably increasing the degree of key-bending.

Despite its great advance over Arnaut's instrument, the clavichord of the Urbino intarsia is clearly transitional and is still quite unlike existing instruments. Its keys are still very bent, it has comparatively few strings — only 17 pairs — for its 47 keys, and its keyboard lacks sidepieces. In addition, the soundboard bridge is much more like that of a viol than of any surviving keyboard instrument.[24] The extraordinary height of this bridge is a direct consequence of the low placement of the soundboard. In the surviving clavichords, the soundboard is set at a level somewhat above the upper surface of the keys. In the Urbino intarsia, the soundboard is clearly shown to be placed near the bottom of the case, and it almost certainly ran beneath the keys. Arnaut refers to this practice in a cryptic remark: "Some make clavichords in which the bottom is not double except from *f* [*f′* in Arnaut's system] to the right-hand end of the instrument."[25] He subsequently states that the distance between the two "bottoms" was

[23]This layout was derived from the perspective view in the intarsia with the assistance of Joseph D'Amelio of Cooper Union University, whose kindness is gratefully acknowledged.

[24]The viol-shaped bridge may well have been standard in 15th-century clavichords. In addition to its appearance in the Urbino intarsia, it is shown in the representations listed as numbers 6 and 9 in footnote 2, and these three representations are just those that show bridges with any clarity.

[25]"Nota quod aliqui faciunt clavicordia in quibus fundus non est duplus nisi ab f cum uno puncto inclusive usque ad finem a parte dextra." Fol. 129v.

one-third the height of the case,[26] which would place the upper "bottom" at much the same level as the soundboard of the instrument shown in the Urbino intarsia. It would, in fact, be most surprising if the soundboard of the Urbino intarsia did not run beneath the keys to some extent, since clavichords made in this way were known at least forty years after the intarsia was executed. The paintings reproduced as Plates 3 and 4 both date from the 1530s and both show clavichords with soundboards set low in the case; in Plate 4, the soundboard is unambiguously depicted as disappearing under the keys. In both of these instruments, however, the keyboard has acquired the sidepieces lacking in the Urbino clavichord. It will also be noted that the keyboard ranges of these North-European instruments are smaller than that shown in the Urbino intarsia. Both keyboards extend only to a'' in the treble, omitting $g\sharp''$.[27]

The keyboard arrangement of the Urbino intarsia was only one of two used in 16th-century Italian instruments. By the middle of the century, when the earliest surviving instruments were built, the 47-key $F — f'''$ arrangement had been replaced by the familiar 45-key $C — c'''$ arrangement with the so-called "short octave" in the bass.[28] Although keyboards that extended down to C were known to Ramos de Pareja in 1482, he states that they then existed only in Spain and were unknown in Italy.[29] Traces of the earlier layout can be detected in a few of the surviving stringed keyboard instruments; thus, it seems likely that the two arrangements coexisted throughout most of the first half of the 16th century, with keyboards outside of Italy generally extending no higher than a''.

The more important change in clavichord design to take place in the first half of the 16th century is that which produced the earliest

[26]" ... notandum quod tota longitudo ipsius clavicordii dividi debet primo in 14 partes equales . . et tres de illis partibus erunt latitudo clavicordii et medietas latitudinis est altitudo tota et distantia inter duos fundos erit medietas unius partis . . " *Ibid.*

[27]It is likely that the instruments had identical $F—a''$ ranges, one tone greater than that given in Virdung's diagrams, and exactly the compass demanded by Hugh Aston's famous *Hornepype*

[28]A single natural key sounding C was added below the existing F, and the missing $F\sharp$ and $G\sharp$ keys were inserted and used for the notes D and E; the lowest octave therefore appeared to begin on E, but actually started on low C and lacked all four accidentals below $B\flat$.

[29]"In Hispania vero nostra antiqua monochorda et etiam organa in *c* gravi reperimus incepisse. Sed modernorum polychorda et etiam organa octo voces sub *c* gravi in ordine ponunt naturali. Non tamen habent voces coniunctas ♮ quadrati sive ♭ mollis sub proslambanomenon. sed tantum est diapente recta sub Ut. . .Iam hic Bononiae repperimus polychordum. sed sub *c* *fa-ut* non nisi in Hispania." Ed. J. Wolf, p 37.

surviving instruments from the type shown in Plates 2, 3, and 4. This change was the raising of the soundboard to a level above the keys, and it is comparable in importance to the abandonment of the all-strings-in-unison design in the closing years of the 15th century. The layout drawings of Arnaut's clavichord and the instrument depicted in the Urbino intarsia (Figs. 3A and 3B) show that the keyboards of these instruments were almost perfectly centered in one of the long sides of the case, with the case extending only a few inches to the right of the topmost key. The soundboards appear to be tiny, but this appearance is deceptive, since a substantial portion of them is hidden by the keys. (In Arnaut's clavichord the hidden portion amounted to at least half the total soundboard area.) Raising the soundboard above the keys meant that no part of it could extend to the left of the topmost key. Consequently, if the soundboard area was not to be drastically reduced, the soundboard had to be bodily shifted to the right at the same time that it was raised. This, in turn, required that the case be extended to the right of the keyboard, producing an instrument in which the keyboard was clearly to the left of center (see Fig. 3C).

Although the soundboard was moved to the right, the position of the bridge could not be changed. Shifting the bridge to the right would have increased the sounding length of the string for the highest note and, with it, the sounding lengths of all the strings that were struck by two or more tangents. Any such general increase in sounding lengths would have increased the spread between tangents striking the same string, which would have increased the degree of key-bending. Thus, the bridge had to remain at the same distance from the topmost key as before, and the net effect of raising the soundboard and moving it to the right was that the bridge was reduced in height and placed near the left-hand edge of the soundboard. The restrictions on bridge placement for those strings struck by two or more tangents did not apply to the tenor and bass strings struck by only a single tangent. Without introducing any new complications, the sounding length of these strings could be made as long as the newly lengthened case would permit. Since long bass strings sound better than short ones, the 16th-century builders took advantage of this opportunity to improve the sound of the clavichord's low register by allowing the tenor and bass strings to run over one or, more usually, two separate bridge segments placed farther to the right than the bridge for the treble strings.

In order to provide the best possible reinforcement of vibrations of

the bass strings, the bridge segment over which these strings pass should be surrounded by a generous amount of soundboard; thus, it is most odd that, in surviving clavichords with segmented bridges, the bass segment is almost always set quite close to the right-hand edge of the soundboard. Although this placement maximizes the sounding lengths of the bass strings, thereby improving their tone quality, it tends to reduce the volume of the sound that they produce. Since this effect can hardly have been unintentional, one is led to conclude that the 16th-century builders chose the placement of the tenor and bass bridge segments with a view to achieving the best possible balance between the bass and treble registers of their instruments.

If the shifting of the soundboard to the right worked primarily to the benefit of the tenor and bass registers, the raising of the soundboard worked primarily to the benefit of the treble. Treble strings are best served by a bridge of small mass, and the tall bridge required by the low soundboard of the earlier clavichords doubtless absorbed much of the energy of the treble strings instead of transmitting their vibration undiminished to the soundboard. Consequently; the reduction in the height of the bridge must have yielded a highly desirable increase in the volume of the upper range of the instrument.

All in all, the improvement in the sound of the clavichord that resulted from raising the soundboard can hardly have been less than radical, and this fact goes far to explain why not a single low-soundboard clavichord still survives.[30] It is even rather surprising that one existed as late as the 1630s among the props in Rubens's workshop: the St. Cecilia of this period attributed to his studio[31] shows a typical low-soundboard clavichord with a range of C — a''. It would seem that (as is often the case in religious paintings) the instrument was chosen particularly because it *was* already very old.

The results of the design revolution outlined in the preceding paragraphs can be seen in Fig. 3C, which shows the layout of a clavichord formerly in the Heyer Collection[32] and now preserved in

[30]One curious feature of a number of the oldest extant clavichords may, in fact, represent a vestigial survival of the earlier practice. In such instruments as the 1543 Domenicus Pisaurensis and the 1568 Onesto Tosi the layout of which is shown in Fig. 3D, the right-hand half of the soundboard slopes downward, requiring that the tenor and bass bridge segments be taller than the treble segment.

[31]New York, Metropolitan Museum of Art, Accession Number 29.100.14. Bequest of Mrs. H. O. Havemayer.

[32]Number 2 in Georg Kinsky, *Musikhistorisches Museum von Wilhelm Heyer in Cöln, Katalog I*, Cologne, 1910. The instrument bears the date *AD/1562* written beneath the keyboard.

the Instrument Museum of the Karl-Marx-Universität, Leipzig. Although this instrument was built between the dates of the earliest signed and dated clavichords of undisputed authenticity, the 1543 Domenicus Pisaurensis (also in Leipzig) and the 1568 Onesto Tosi (in the Boston Museum of Fine Arts),[33] it seems to be of an earlier design. The arrangement of tangents in the 1562 Leipzig instrument, given in the third column of the table, is the same as that shown in the Urbino intarsia, except that each of the added notes in the bass — *C*, *D*, and *E* — has its own pair of strings. The loss of the notes $c\sharp'''$ to f''' saves one pair of strings in the treble, with the result that there is a net increase of only two pairs of strings — from 17 to 19. The Pisaurensis clavichord and the Tosi (the layout of which is shown in Fig. 3D) have identical tangent arrangements. In both instruments strings appear to have been added specifically for the purpose of further reducing the spread of the keys in the bass. As shown in the fourth and fifth columns of the table, the number of bass keys given their own strings was increased from eight to eleven, and the following group of four tangents was broken up into two groups of two. In this way, three pairs of strings were added, bringing the total to 22 pairs.

Although all the extant mid-16th-century clavichords seem to be of Italian origin, it is possible to demonstrate that the clavichord in Spain must have been quite similar, at least in the number of strings it possessed and in the way in which its tangents were arranged. Both Juan Bermudo[34] and Tomás de Sancta Maria[35] provide keyboard diagrams for clavichords. These show a range of $C - a''$ with the usual short octave in the bass, requiring a total of 42 keys. According to Bermudo, the clavichord of his day had 42 strings.[36] Although the coincidence between the number of keys and the number of strings is a trifle suspicious,[37] 21 pairs of strings with the tangents arranged as in

[33]Number 1 in Kinsky, *op. cit.* and number 299 in Nicholas Bessaraboff, *Ancient European Musical Instruments*, Cambridge, Mass., 1941, respectively.

[34]*Declàración de Instrumentos musicales*, Osuna, 1555, fol. lxij.

[35]*Libro llamado Arte de tañer Fantasia . . .* , Valladolid, 1565, fol. 56.

[36]"Siempre han procurado de augmentar las cuerdas en este instrumento hasta el tiempo presente: en el qual tiene quarenta y dos cuerdas, y puede tener mas." Fol. lxjx v.

[37]Bermudo does not seem to have known of a name by which to distinguish the virginal from the clavichord, which he called a *monochordia*. On fol. lxjx, he refers to instruments "on which each string forms its own note." ("Otros instrumentos ay de teclas y teniendo-muchas cuerdas, y caseciendo de dos dichos paños: cada cuerda forma su boz.") Such instruments can only have been virginals, and one wonders whether a clavichord really is meant when Bermudo mentions the continuous increase in the number of strings to 42.

TANGENT GROUPINGS ON EARLY CLAVICHORDS

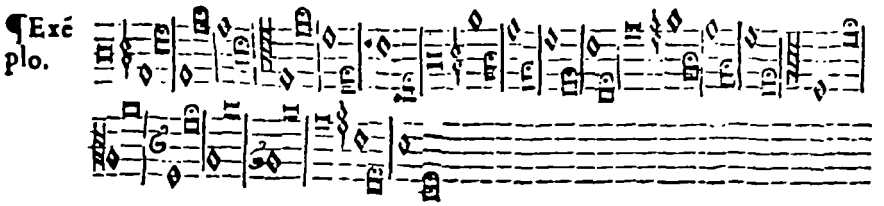
Arnaut Reconstr. (10 choirs)	Urbino Intarsia (17 choirs)	Leipzig Anon. (19 choirs)	Domenicus Pisaurensis (22 choirs)	Onesto Tosi (22 choirs)	Sancta Maria's Tuning
		C	C	C	C
		D	D	D	D
		E	E	E	E
	F	F	F	F	F
	G	G	G	G	G
	A	A	A	A	A
	B♭	B♭	B♭	B♭	
B	B	B	B	B	B
c	c	c	c	c	c
c♯	c♯	c♯	c♯	c♯	c♯
d	d	d	d	d	d
e♭	e♭	e♭	e♭	e♭	
e	e	e	e	e	e
f	f	f	f	f	
f♯	f♯	f♯	f♯	f♯	
g	g	g	g	g	g
g♯	g♯	g♯	g♯	g♯	
a	a	a	a	a	
b♭	b♭	b♭	b♭	b♭	
b	b	b	b	b	
c'	c'	c'	c'	c'	c'
c♯'	c♯'	c♯'	c♯'	c♯'	
d'	d'	d'	d'	d'	
e♭'	e♭'	e♭'	e♭'	e♭'	
e'	e'	e'	e'	e'	e'
f'	f'	f'	f'	f'	f'
f♯'	f♯'	f♯'	f♯'	f♯'	
g'	g'	g'	g'	g'	
g♯'	g♯'	g♯'	g♯'	g♯'	
a'	a'	a'	a'	a'	a'
b♭'	b♭'	b♭'	b♭'	b♭'	
b'	b'	b'	b'	b'	
c"	c"	c"	c"	c"	c"
c♯"	c♯"	c♯"	c♯"	c♯"	
d"	d"	d"	d"	d"	
e♭"	e♭" [1]	e♭"	e♭"	e♭"	
e"	e"	e"	e"	e"	e"
f"	f"	f"	f"	f"	
f♯"	f♯"	f♯"	f♯"	f♯"	
g"	g"	g"	g"	g"	g"
g♯"	g♯"	g♯"	g♯"	g♯"	
a"	a"	a"	a"	a"	
b♭"	b♭" [2]	b♭"	b♭"	b♭"	
b"	b"	b"	b"	b"	
	c‴	c‴	c‴	c‴	
	c♯‴ [2]				
	d‴				
	e♭‴				
	e‴				
	f‴				

[1] Placement of this tangent is not clear.

[2] These tangents omitted on the intarsia.

the Tosi clavichord suffice exactly for the slightly smaller range of Bermudo's instrument.

The evidence provided by Sancta Maria gives even better confirmation of the similarity between Italian and Spanish instruments of the mid-16th century. At the end of his book,[38] Sancta Maria provides a method for tuning the clavichord, appending the following illustration, in which each breve indicates the note to be tuned from the preceding semibreve:



Courtesy Sibley Music Library, Eastman School of Music, University of Rochester

Unfortunately, the tuning of only the first ten notes (measures 1-6 of the *exemplo)* is described in the text, and an error of some kind occurs in the *exemplo* immediately thereafter: mm. 7 and 8 repeat the tunings accomplished in mm. 5 and 2. Nonetheless, if all the notes tuned are tabulated as shown in the last column of the table, it can be seen that Sancta Maria's method would work almost perfectly for tuning an instrument with its tangents arranged like those on the Pisaurensis and the Tosi. Only a single note in each tangent group is employed, and with but two exceptions each tangent group is accounted for. It seems clear that the two redundant tunings were intended for the missing *B*♭ and *f,* especially since Sancta Maria states that each key below *d* had its own pair of strings.[39]

The purpose of this article has been to trace the development of the clavichord from the 15th century, when we have only pictures and documents to guide us, to the middle of the 16th century, when we have surviving instruments as well. Although the clavichord had by 1550 reached a point only about halfway between Arnaut's instrument of 1440 and the kind known to Bach, its subsequent development was already predetermined.

[38]Ch. LIII. The *exemplo* appears on fol. 122v.

[39]"...desde desolre para abaxo, desde el qual cada tecla por si, hiere dos cuerdas." Fol. 122v. Of course, it is not vital that *f* be tuned, since the four-tangent group *e*♭ — *f*♯ may not have been broken into two groups of two on Sancta Maria's instrument.