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## ABSTRACT.

Meantone is reputedly the temperament for early keyboard instruments. General references are made to it as one of the precursors of equal temperament, and "Das Wohltemperierte Clavier" is often cited as one of the main turning points in the history of keyboard temperament, Bach being held as a champion of equal temperament at a time when meantone was the accepted temperament. Looking further back into the history of keyboard music we would expect to find meantone firmly established as the standard temperament, but the issue is complicated by a Fantasia by John Bull, the difficulties of which can only be explained by reference to equal temperament.

If equal temperament is accepted as necessary for the Bull Fantasia, certain questions immediately spring to mind. How strongly was meantone the established temperament for keyboard instruments if equal temperament was known to one of the earliest schools of keyboard music? How can "Das Wohltemperierte Clavier" be considered as such an important milestone in the history of keyboard temperament if equal temperament was conceivable at the beginning of the seventeenth century or even earlier? Finally, if equal temperament was known at the beginning of the seventeenth century, and firmly established in the first half of the eighteenth, why did a firm such as John Broadwood and Sons only make equal temperament its standard keyboard temperament as late as 1846?

Dr. J. Murray Barbour has cast serious doubts on the assumption that Bach intended "Das Wohltemperierte Clavier" for an equally tempered instrument, whereas a glance at mid-nineteenth century keyboard music, with its enharmonic changes, makes anything other than equal temperament impossible, but the question of the chromatic notes in the works of the English virginalist composers has yet to be fully investigated.

This study is an attempt to bring together information about the music of the late sixteenth and early seventeenth centuries and the temperaments and instruments available from which to draw conclusions about the most likely temperaments to have been in use. The available material strongly suggests quarter comma meantone as the standard temperament, and there is sufficient evidence in the music to support the notion that the dissonance caused by the occasional substitution of an E flat for a D sharp was tolerated, while at the same time it seems clear that the Bull Fantasia was written for a clavicymbalum universale, an instrument which offered exactly the nineteen different notes which Bull required for this piece.

THE TEMPERAMENT OF KEYBOARD INSTRUMENTS  
IN ENGLAND DURING THE LATE SIXTEENTH  
AND EARLY SEVENTEENTH CENTURIES.

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## PREFACE.

A study of the music of the English Virginalists, with the aim of ascertaining the most likely temperament used, is long overdue. Since equal temperament became the established keyboard temperament, all keyboard music has been subjected to its use, irrespective of historical accuracy. Early music is enjoying a considerable revival, but the efforts being made to give authentic performances have not yet extended to temperament. Information about possible temperaments is not far to seek in sixteenth and seventeenth century writings, but a detailed study of the evidence available in the music has not previously been undertaken.

On a plucked string keyboard instrument the "running thirds" of equal temperament are much more noticeable than on a piano. The "stillness" of a pure major third is so obviously "right" for such instruments that the criticisms of equally tempered thirds by musicians who were used to pure thirds can easily be appreciated, but it is difficult to find keyboard instruments which are tuned to any other than equal temperament. The Russell Collection of Early Keyboard instruments at the St. Cecilia Hall, Edinburgh, presents one of the few opportunities to see and play upon instruments tuned to various temperaments. I would like to express my thanks to Dr. Peter Williams, director of the Russell Collection, for allowing me to play on the instruments as well as the McClure organ in the Reid School of Music. I would also like to thank John Barnes, curator of the St. Cecilia Hall, who gave so generously of his time and knowledge, and allowed me to listen whilst he tuned instruments for concert purposes.

My thanks also to the staff of Durham University Library for their assistance in tracking down the necessary books, particularly the then elusive Tuning and Temperament by Dr. Murray Barbour, which has now, happily, been reprinted and is more generally available.

Above all, I wish to thank Dr. Jerome Roche, who, in spite of his many commitments, always found time to advise and discuss, and has guided this study near rocky shores and through narrow straits with a firm but gentle hand.

CHAPTER 1.

INTRODUCTION.

.... the rewards for the advancement of secular learning were not usually very great and the dangers were often considerable in an age which found it hard to differentiate between science and magic and mere witchcraft. Not until the ideas and the knowledge of the learned had been assimilated by men of affairs, by businessmen and merchants, navigators and engineers, could there anyway be that blend of theory and practice which was later to produce first the 'scientific revolution' and then the 'industrial revolution'. The scholars and teachers of the later sixteenth century were mostly absorbed in the humbler task of trying to sort out those ideas and of diffusing that knowledge. Their main efforts were expended in popularising and describing; in defining and pointing out the problems rather than in breaking through to new solutions.

It is tempting to see here a reason for the successes of this age, and particularly of its later years, in the one field where its achievements rose far above mediocrity. For in imaginative literature and the drama, in those arts that hold a mirror up to human nature, the late sixteenth century and the first years of the seventeenth century soared to heights that in other fields seemed quite beyond the reach of the men of those times. In vernacular literature and drama, and in music, Cervantes and Shakespeare, Palestrina and Byrd, and their fellows, brought to brilliant maturity the strivings of the preceding generation. In painting and architecture, too, the inspiration of the High Renaissance was passed down by way of Titian and El Greco, to the seventeenth century. (1)

The above quotation, taken from the concluding paragraphs of the introduction to a book on the Counter Reformation, hints clearly at the disparity in various fields of human endeavour during the latter half of the sixteenth and the beginning of the seventeenth centuries. To say that it was a period of change, a period of discovery, a period in which ideas were formed which would be put to more practical use by succeeding generations is to equate it with almost every other period of history. That it was such a period is undeniable, but a closer look at the nature of some of these changes and discoveries helps in understanding the period, just as a knowledge of what followed reveals their ultimate significance.

Much has been written about the revival of classical antiquity as characteristic of the Renaissance. Scholars looking back beyond the medieval culture which glorified God and heaven saw one which glorified man and the world in which he lived. The interest in classical antiquity was not unprecedented, as the Carolingian Renaissance of the ninth century and the Ottonian of the tenth as well as the Renaissance of the twelfth century can testify, nor had the great classical writers been forgotten in the Middle

(1) Wernham, R.B. (ed.) The New Cambridge Modern History. Vol. iii Cambridge. 1968.

Ages, the philosophies of Plato and Aristotle having contributed much to medieval philosophy, and the writings of Virgil, Ovid, Lucan, Juvenal and Horace retained their popularity. It was not so much the re-discovery of antiquity as the approach to it which made the difference between the Middle Ages and the Renaissance; henceforth it was to be that man and God would go forward together rather than that God, through the Church, should always lead, or, even more radically, that, "what the Middle Ages established through the Church was now attempted outside the Church." (2)

The change, however, was not sudden. As with most changes in history the process was slow and not always easy to follow even in retrospect. Much which could be called medieval lived on into the Renaissance just as much which truly belonged to the Renaissance survived into the Baroque. Even the word Renaissance itself presents difficulties; it is almost synonymous with humanism. The humanist of the sixteenth century was not one who had rejected God in favour of man, he was one who, by cultivating the classics, had come to accept man as a being of importance rather than solely as an instrument through which the glory of God could be recognised. M.L. Bush sums up the position:

It is true that the superiority of man among earthly creatures, emphasised both by the Greeks and in the book of Genesis, had never been forgotten..... But during the course of the fourteenth and fifteenth centuries, and largely under the influence of antiquity, the importance of man in a much broader sense became a prominent feature in Italian art, literature and philosophy. The relationship between man and God remained an overriding concern, but, in addition, the relationship between man and man, and the relationship between man and his surroundings became increasingly a worthy consideration of artists and writers. (3)

Renaissance has come to be the word which signifies the artistic style of the period, the word which brings to mind its tangible evidence in the form of painting, architecture and music, but humanism, or a feeling for man's achievements, describes its spirit.

It is perhaps to be expected that an age which sought to express the importance of man in the universe would begin to seek explanations of natural phenomena in terms of man's understanding rather than as manifestations of the divine will. There was a resurgence of the idea that such phenomena could be studied as physical facts of this world, and that these facts could be pieced together to add to man's knowledge of his environment and to help him overcome some of the limitations of that environment.

(2) Lang, P.H. Music in Western Civilisation. London. 1942.

(3) Bush, M.L. Renaissance, Reformation and the Outer World. London. 1967.

Nowhere was the fight against limitations more apparent or the winning of that fight more rewarding than in the realm of seamanship. It was not sufficient that a skilled sea captain could take his ship over uncharted waters, find new, interesting and commercially desirable lands, and then return safely to tell his story. He had to be able to return to those lands at will and to do so in the shortest possible time. The two main aids of the shipmaster, the compass and the lead, were not enough to enable him to determine his position well away from any known landmarks. Eventually the log helped to give a more accurate estimate of speed than the older method which was to record the time taken to pass a piece of flotsam or other floating debris, and the quadrant was replaced by the more reliable astrolabe or "sea ring" as a means of determining latitude, but it was not until the invention of the chronometer in the eighteenth century that longitude could be accurately established; the Renaissance method of 'running down the latitude', however, served pretty well in the meantime. "In the story of discovery in the broadest sense, then, our period was a time of tentative, though splendid, beginnings. 'The Age of Reconnaissance' seems the most appropriate name by which to describe it." (4)

Natural science was closely allied to the study of medicine. Botany was valued because of the information it gave about herbs which could be used as remedies for man's ailments, and zoology because of the assistance it offered to a greater understanding of the human body. Important discoveries were made such as the realisation of William Harvey (1578 - 1657) that blood flowed in one direction only and that the valves in the veins, the existence of which had been known for some time, were there to ensure this unidirectional flow. The standard of surgery improved under the influence of men like William Clowes (1544 - 1604), and although the profession of barber - surgeon continued there was more stress on the surgery and apprentices were required to attend lectures at the Barber-Surgeons Hall in London from such men as William Clowes and John Caius. Certain chemical remedies were being introduced but were very suspect because they were not, as yet, completely understood, although some, such as antimony, were being controlled during the early years of the seventeenth century.

Against this background of progress it must be remembered that science, as we know it, was still considered to be a form of magic. There were,

(4) Parry, J.H. The Age of Reconnaissance. New York. 1963.



however, two sorts of magic, as J.B. della Porta (c. 1535 - 1615) points out:

There are two sorts of Magick; the one is infamous, and unhappie, because it hath to do with foul spirits, and consists of Inchantments and wicked curiosity; and this is called Sorcery..... The other Magic is natural; which all excellent wise men do embrace, and worship with great applause; neither is there any more highly esteemed, or better thought of, by men of learning. (5)

Porta's Natural Magick from which the above quotation is taken, was first published in 1558 and appeared in many different editions after that date.—Its subject matter ranged widely, including the beautifying of women, the counterfeiting of gold, cookery, optics, hydraulics, pneumatics and the wonders of the loadstone. This book was a popularised version of natural magic and is of a low level, yet it was included by William Gilbert in his review of the literature of magnetism, whose Treatise on the Loadstone and Magnetic Bodies comes into the category of learned rather than popular science.

In classical times music had been regarded primarily as a science, and remnants of this belief persisted into the Renaissance and well into the Baroque. Friedrich Blume gives us this timely reminder:

The artists of the Renaissance felt the need to couch in rules their wealth of sensual experience; like the artist of the twentieth century, they theorised because they felt the solid ground of tradition quaking beneath their feet, and they clung to what was logically and mathematically graspable to avoid drowning in the ocean of the senses. Hence their need for a norm, which is much more 'medieval' than 'modern' in effect and which makes itself especially strongly felt in music. To this should probably be added a further motive, the inclination to 'Gelehreit', music, for example, still being a scientia. Like the artists of the Baroque, those of the Renaissance liked to consider themselves 'scientific' and thus on the same level with the scholars. This motive behind their endless theoretical reasonings should not be overlooked. (6)

That English theorists subscribed to the view that music was a science is born out by the preface to John Playford's An Introduction to the Skill of Musick (1674) and the dedication of The Division Viol by Christopher Simpson (1659), yet Thomas Morley held firmly to the view of the musician as artist. In his address 'To the Courteous Reader' he says:

- (5) Porta, J.B. della Natural Magick. In xx Books. London 1669.
- (6) Blume, Friedrich. Renaissance and Baroque Music. New York 1967.  
(Tr. by M.D. Herter Norton)

....this work which now I publish to the view of the world, not so much seeking thereby any name or glory.....as in some sort to further the studies of them, who, being endued with good natural wits and well inclined to learn that divine art of music, are destitute of sufficient masters. (7)

It was, then, partly as artist and partly as scientist that the musician viewed himself, and, no doubt, as other people viewed him. It is not unlikely, too, that he was considered somewhat of a magician, especially if his personal ability as an instrumental performer was of a particularly high standard.

The quotation which opened this chapter singles out the achievements of the musician as creative artist as being among the triumphs of the late sixteenth and early seventeenth centuries, but the activities of musicians also reflected the general spirit of the period. Byrd's church music is unsurpassed, but he was one of the first composers to find keyboard instruments a fitting means of artistic expression. This duality of feeling for the sacred and the secular is present not only in his choice of media, but also within the scope of his keyboard music itself where such titles as Gloria Tibi Trinitas, Clarifica Me, Pater Salvator Mundi, and, John Come Kiss Me Now, The Woods So Wild and Lavolta appear in close proximity to each other. The desire to recreate the three Greek genera, diatonic, chromatic and enharmonic, induced scholars to devise, and craftsmen to build, keyboard instruments with more than the normal twelve notes to the octave, whilst theorists were at the same time interested in Greek drama. As well as its artists and craftsmen, music had its 'scientists' in men like Mersenne who was by training and inclination a man of science, but whose encyclopaedic work Harmonie Universelle touches upon almost every phase of musical life; theory, performance and composition.

In such an age, it is perhaps fitting that a subject such as temperament, which stands on the borderline between the art and the science of music, should be given special consideration. Friedrich Blume makes reference to similarities between the later sixteenth and early seventeenth centuries and the twentieth century (8); another similarity might be that interest in temperament is due for a revival in our scientifically orientated age. Whether this is likely or not is open to

(7) Morley, Thomas. A Plain and Easy Introduction to Practical Music. London 1597. (Ed. Alec Harman 1963)

(8) See page 4.

question, but in the intervening centuries and even in the present century many of the comments made on temperament have been somewhat confused and misleading as the following chapter will try to show, and point to the conclusion that a comprehensive study of temperament is perhaps already overdue.

CHAPTER 2.

KEYBOARD TEMPERAMENT: SOME CONFLICTING VIEWS

Along with the mounting interest in early music which is evident new from a glance through a modern record or music catalogue or a copy of the Radie Times, has come a great deal of information about the performance of such music. Excellent new editions of works appear frequently, old books on ornamentation, realisation of basses, and performance in general are reprinted either as facsimile editions or translated and edited so as to make the information more readily comprehensible to present day-musicians, or new books are produced on the subject by modern scholars.

What is true of the music in general, is also true of keyboard music in particular, but one important area of the latter, namely temperament, is given very little attention. It is true that it is mentioned in most of the writings at least somewhere (it would be very difficult not to give it some passing comment), but the information given is usually scanty and inconclusive, and some of it vague and misleading.

A discussion of temperament is much more germane to a discussion of keyboard music than to vocal music or music for instruments which can vary their pitch in performance. But it is net out of place in discussing music other than that for keybeard. Singers and instrument-  
alists other than keyboard players must temper the intervals they play or sing. They must do so, obviously, when they are playing together with a keyboard instrument, but even without this restriction, their intervals will need to be tempered from time to time, otherwise they would have difficulty in keeping in tune with each other and within the confines of a key. This form of temperament is flexible and depends on the ear, technical ability and musical taste of the performer. Keyboard temperament is fixed in the act of tuning, remains unalterable in performance, and even in a recital can be varied only slightly between works unless several instruments bearing different temperaments are available.

The temperament used could be governed, in our time, by the type of music being played, but this oppertunity is seldom taken. Equal temper-  
ament seems to be the only temperament we accept. Whilst the temperament could be governed by the type of music if we so wished, the converse is also likely to be true, that for a long period of time, keyboard music was governed by the temperament. Meantone temperament set the bounds of

keyboard modulation for a considerable length of time, until, as with all restrictions, the desire to extend and enlarge, broke it down. Although the desire to expand and free oneself from restrictions is a necessary part of human development, the breaking of the restriction is not wholly gain, and things of considerable beauty or utility can be lost. This need not be the case so far as temperament is concerned, and there are signs that meantone and other temperaments are making a limited reappearance, but until some of the apparent contradictions are sorted out and some of the prejudice broken down, it will be difficult to reintroduce these temperaments into public performances. Extending this into the amateur field, until there are more spinets, harpsichords, clavichords and virginals in use, and information or training available for people to tune their own instruments, it will be difficult to bring these temperaments into any other than limited areas of private music making.

The period covered by this study is that generally known as the period of the English Virginalists, and extends from the last quarter of the sixteenth century to the middle of the seventeenth century (roughly covered, in fact, by the complete life span of Thomas Tomkins : 1572 - 1656). General references to temperament up to the late eighteenth and nineteenth centuries imply that meantone was used. Dispute arises over the temperament used by Bach in 'Das Wohltempierte Clavier', but it seems to be agreed that nineteenth century musicians accepted equal temperament for their keyboards, although the exact point in the century when it can be clearly stated that other temperaments were abandoned is difficult to establish. Statements such as the following are typical of these generalisations.

The important thing to realise about meantone is that it is not just a laboratory experiment in acoustics. It was for centuries considered to be the proper temperament for keyboard instruments, and anyone who sang or played in consort with a keyboard instrument was expected to conform to it. (1)

The above passage by Thurston Dart, although pointing out quite emphatically that meantone was used as the standard keyboard temperament 'for centuries', does not specify which centuries. Since the English virginal school was the first great school of keyboard music, and equal temperament was not fully established until the nineteenth century, then at least one of the 'centuries' referred to must include this school.

(1) Dart, Thurston. Interpretation of Music. 4th edition. London 1960. p.48.

To support the date at which equal temperament was adopted, I quote from the Harvard Dictionary.

The introduction of equal temperament into practical music was very slow. Whether Bach's famous collection of pieces in all the major and minor keys, *The Well-Tempered Clavier* (1722 - '44) or its less complete predecessor, J.K.F. Fischer's *'Ariadne Musica'* (1715), referred to equal temperament or merely a close approximation is not entirely clear. At any rate, the system was not universally adopted in Germany until c.1800, and in France and England until c.1850. (2)

This passage is more exact about the time at which equal temperament was adopted, but it does not say which temperaments it superseded. A little more help is given earlier in the same article in the Harvard Dictionary. After commenting on the problem of enharmonic change, in particular, G sharp for A flat, it says:-

A better expedient is the use of divided keys, which, as a matter of fact, were not infrequently used in organs of the 16th century. However even this improvement did not meet the needs of the more fully developed harmonies, modulations and keys used during the 17th century. The increased use of keys with three to six sharps and flats necessarily led to the system of equal temperament. (3)

The article then goes on to describe equal temperament. This leaves a very large gap. Enharmonic problems in the sixteenth century, (the implication that there was a G sharp but no A flat seems to point to meantone), the harmonic needs of the seventeenth century 'not met', no reference to the eighteenth century, except that to Bach quoted above, and equal temperament in the nineteenth century, leave a lot to be supplied by the imagination.

Other modern books are equally unhelpful, F.E. Kirby's A Short History of Keyboard Music does not give a mention to temperament in its index, and only a passing reference is given to it in the text. When speaking of Bach's Preludes and Fugues he says:

The designation "well tempered" has to do with Bach's adoption of even temperament (in which the octave is divided into twelve equal parts or semitones) in place of the meantone system, which had been in use since the Renaissance and which worked out well enough as long as one did not exceed the keys with signatures greater than two sharps or flats. (4)

- (2) Apel, Willi. Harvard Dictionary of Music. 2nd edition. London 1970. p. 836.  
 (3) Ibid. p. 835.  
 (4) Kirby, F.E. A Short History of Keyboard Music. New York 1966. pp. 127-8.

This reference is quite clear, except for the term 'even temperament', which would appear from the description given to be equal temperament, since 'the octave is divided into twelve equal parts ...' - equal temperament for Bach, meantone before Bach, as far back as 'the Renaissance'.

Robert Donington, in his otherwise very helpful book, The Interpretation of Early Music, is not particularly helpful on the question of temperament. He has, however, a short chapter on the subject from which the following quotation is taken:

Keyboard temperament is a static temperament, which if it flatters some tonalities, can only do so at the expense of others.

Late renaissance and baroque temperaments could flatter the 'near' keys because the 'remote' keys were not in common use.

A favourite was mean-tone temperament.....

He then goes on to give a brief description of the temperament.

He continues:

Among the comprehensive range of temperaments explored by late renaissance and baroque theorists and musicians, some of whose compositions pass through the entire cycle of keys, there were various modifications of mean-tone temperament. .... J. Murray Barbour ('Bach and the Art of Equal Temperament' Mus. Quart. xxxiii, January 1947, p.64) has shown that [a] version of mean-tone temperament with sharp thirds (and not equal temperament as historians have assumed) is almost certainly the temperament for which J.S. Bach showed his practical enthusiasm by composing his Forty-Eight Preludes and Fugues - and much other music in tonalities too remote for normal mean-tone temperament. (5)

Confusion reigns. Meantone tuning was used 'for centuries'; the temperament used by Bach in his Preludes and Fugues is 'not clear' (according to the Harvard Dictionary published in 1970); a 'version of meantone temperament with sharp thirds ..... is almost certainly the temperament for which J.S. Bach showed his practical enthusiasm ...' (in a volume directed solely to Early Music, published in 1963 and supported by research published in 1947); and yet, in a book on keyboard music published in 1966 there is a definite reference to 'Bach's adoption of even temperament' which is described in terms usually associated with equal temperament.

(5) Donington, Robert. The Interpretation of Early Music. London 1963. pp. 447-8.

Most of the reference to temperament in general histories are centred round Bach - meantone before, equal after. Little specific mention is made of the temperaments used for the English virginalists. Writings about this school, however, prove to be equally vague or confusing.

The following quotation, by Charles van den Borren, brings us back to the Bach and equal temperament controversy:-

Another interesting point of view is that of the impossibility of executing the 'Ut, re, mi, fa, sol, la' of Bull on a keyboard instrument the temperament of which does not conform to the equal temperament definitely laid down by J.S. Bach about a hundred years later. In fact, as seen as a piece included other alterations than B flat, E flat, A flat, F sharp, C sharp and G sharp, it was impossible to play it on a harpsichord or clavichord tuned according to the rules of unequal temperament in use in the 16th and the opening of the 17th centuries, without false intonations resulting. Bull must therefore have tuned his clavier to the principles of equal temperament to enable him to perform his 'Ut, re, mi, fa, sol, la' without forfeiting truth of sound.

(6)

Since the above quotation is taken from a work dated 1913 (first published in English translation in 1915), the acceptance of Bach and equal temperament need not be taken further. The number of accidentals possible in 'unequal' temperament seems rather curious - one more than the five black notes on a keyboard - presumably the A flat was an alternative for G sharp, although the passage does not make this clear. The statement that 'Bull must therefore have tuned his clavier to the principles of equal temperament', however, needs to be followed up. As corroboration for this, a footnote refers the reader to the Fuller Maitland and Barclay Squire edition of the Fitzwilliam Virginal Book. Van den Borren does not quote an actual passage, but makes reference to the introduction. The following appears in the Fuller Maitland and Barclay Squire introduction, in a discussion of temperament and the Bull Fantasia in particular:

If this can ever have been endurable to educated ears some sort of compromise must have been in practice, and the fact that Zarline, before 1588, had advocated the adoption of the division of the octave into twelve equal semitones for lutes and keyed instruments, suggests that his system may have been put into practice in England at a date long before the universal adoption of the modern method of tempering the scale. (7)

(6) Van Den Borren, Charles. The Sources of Keyboard Music in England. English Translation. London 1915.

(7) Maitland, J.A. Fuller, and Squire, W. Barclay. The Introduction to the Fitzwilliam Virginal Book. 1899. republished 1963.



In addition to their discussion in the introduction to the Fitzwilliam Virginal Book, the editors supply a footnote to the Bull Hexachord Fantasia where it appears as item 51 in the book (page 183). This footnote reads:

This interesting experiment in enharmonic modulation is thus tentatively expressed in the M.S; the passage proves that some kind of 'equal temperament' must have been employed at this date.

Both writers are quite emphatic: the Bull Fantasia was written to be played in equal temperament. No other explanations are offered.

Keeping to the same piece of music, later writers are less convinced. The Harvard Dictionary, in the article on the 'Arcicembalo', describes an instrument by the 'Belgian Charles Luython' called a 'clavicymbalum universale' and goes on to say without qualification of the statement:

Compositions such as John Bull's fantasia on the hexachord "Ut, re, mi, fa, sol, la" (Fitzwilliam Virginal Book i 183) are evidently written for this instrument. (8)

J. Murray Barbour does not approve of the findings of Fuller Maitland, Barclay Squire and van den Borren either. He gives warning that one should not try

to build up a theory of the use of equal temperament in England during Queen Elizabeth's reign on the basis of Dr. Bull's composition. Remember that it stands alone. It seems almost as if Bull had written a Fancy for four viol, and then by some mad whim, had transcribed it for virginals and tuned his instrument to suit. (9)

This is an interesting theory, since another Fancy, this time by Tomkins, also creates problems with regard to the temperament used, and the Tomkins Fancy is admittedly 'for viols'. The question is, to which temperament did this 'mad whim' lead him to tune the instrument?

Peter Yates has little doubt about the temperament used:

The tempered Pythagorean tuning is very effective for the playing of the earliest keyboard music and for the English keyboard music as late as Purcell. It solves the problem of the modulations in the famous Hexachord by John Bull so effectively that, on the example of this piece alone, the use of tempered Pythagorean for the English Elizabethan music seems very probable - although for a considerable part of the literature a straight Pythagorean would suffice. (10)

(8) Apel, Willi. Op. Cit. p. 48-9.

(9) Barbour, J. Murray. Tuning and Temperament. A Historical Survey. East Lansing. 1951.

(10) Yates, Peter. An Amateur at the Keyboard. London 1965. p.256.

The discussions on temperament in the seventeenth century centre round the Bull Hexachord Fantasia much as they centre round the Preludes and Fugues of Bach in the eighteenth century. General comments on the temperament used are equally divided. To return to van den Berren. At the end of The Sources of Keyboard Music in England, the following two paragraphs appear:

A few words, in conclusion, as to the temperament. We have seen previously (p.328) that the performance of the first 'Ut, re, mi, fa, sol, la' of Bull was inconceivable without applying to the clavier a sort of equal temperament. It is certain that this necessity extended to other virginalistic pieces than this scholastic work of Bull, and that composers found themselves in this respect in an entirely different situation from that of about the middle of the 16th century, when the Spaniard Bermude placed a crowd of restrictions on the most innocent transpositions, on account of the unpleasant dissonances which resulted under the sway of unequal temperament.

We saw above that the virginalistic repertory contains E flat and D sharp, sounds very different from each other in the scale of fifths. The D sharp is not very uncommon with the virginalists of the last thirty years of the 17th century; the E flat is very common, and we meet with even an A sharp in certain pieces. As it is obvious that they did not tune the instrument with a special view to a particular piece written in a particular tonality, it must be admitted that they applied a unified system of tuning, thanks to which a black key representing B flat could be used as A sharp, without any dissonance occurring. Now this was only possible by means of the use of equal temperament, or of something very like it. (11)

The following clause from the penultimate sentence is in question here, 'As it is obvious that they did not tune the instrument with a special view to a particular piece in a particular tonality ....' No evidence is given that 'they' did not, but it is certain that many of 'them' could have done so. The main clause of the same sentence is also open to doubt since a 'unified system of tuning' is accepted but not corroborated.

Referring again to the introduction to the 1899 edition of the Fitzwilliam Virginal Book, the general remarks about tuning are very misleading. I quote extracts from the final few paragraphs (it is strange how temperament so often finds its place at the end of the queue, if included at all):

It is always taken for granted that keyed instruments were tuned in just intonation, in such a way that while the keys nearly related to C major were more or less exactly in tune, those keys which are represented by a greater number of sharps and flats were execrably discordant .....

But if we take it for granted that just intonation was the almost universal rule, it is not less clear that some method, possibly a rough and ready one, of obtaining something like temperament was in use at the time of date of this M.S.

(12)

The writer(s) here are very tentative. The very vagueness shows that these are not the words of conviction. Even the terms themselves are misleading. 'Just intonation' is mentioned twice in the passage quoted (and elsewhere as well), but the description fits meantone temperament better than just intonation, and I would find it difficult to fit my notion of just intonation into the context of the passages. The words, 'something like temperament', presumably refer to equal temperament, but the writer(s) are very careful to avoid committing themselves on this point.

Hilda Andrews makes several references to the temperament of the instruments which might have been used to play the pieces in My Ladye Nevell's Booke in her edition of that book. On page xxix she writes, as a footnote:

The sung effect of such "false relations" is, of course, softer than is possible on a keyed instrument like the virginal, which must have been tuned on some system of equal temperament.

(13)

She takes up the subject of temperament again on page xxxiii:

The question of equal temperament of the virginal was raised on a previous page in the discussion of 'false relations'. It cannot be disputed that some such system was in use for keyed instruments in Byrd's time, if not before. There is sufficient evidence of this in the use of D sharp and E flat, and of G sharp and A flat in virginal music, and even in the same piece, implying a system of tuning in which D sharp and E flat were identical, and G sharp and A flat. In just temperament this would, of course, not be the case. The conclusion to be drawn is that some system of dividing the scale into twelve equal semitones must have been used.

(14)

- (12) Fuller-Maitland, J.A. and Squire, W. Barclay. Op. cit.
- (13) Andrews, Hilda. Historical Note to My Ladye Nevell's Booke. New York 1926.
- (14) Andrews, Hilda. Ibid. p. xxxiii.

15.

There is no doubt that the sung effect of false relations can be softer than is possible on a keyed instrument, but there is doubt about the deduction drawn in the second quotation and stated without explanation in the first, that the instruments were tuned to 'some system of equal temperament'.

Ernest Walker is more specific and confines his comments on temperaments to yet another discussion of Bull's Hexachord Fantasia, which, he says:

is of special interest by reason of the extreme ingenuity with which the formula is made to appear in many different keys, the method involving rapid modulations, the notation of which is at times complicatedly enharmonic; this piece is indeed remarkable on many grounds, showing that (unless Elizabethan ears were extraordinarily insensitive) some kind of approach to equal temperament must have been known. (15)

In a discussion of false relations later in the same book he refers to 'a system of unequal temperament'. (16) This statement is made about false relations in general rather than in keyboard music in particular, but it seems safe to assume the reference to unequal temperament to be associated with keyboards rather than voices or viols.

To return to the second quotation from Hilda Andrews, there are one or two loose statements which need clarification. 'Some sort of equal temperament' is, in itself, vague. Dr. Walker's 'some kind of approach to equal temperament' is more readily understandable if we accept quarter comma meantone as the standard meantone tuning and then accept that any sharpening of thirds and fifths, either in regular systems, such as 1/5 comma, 1/6 comma etc. which push the 'wolf' further into the remote keys and reduce its size until at 1/11 comma (equal temperament) it disappears completely, or in some irregular systems such as Werckmeister's, in which thirds and fifths varied in size, as all being steps between quarter comma meantone and equal temperament.

The reference to just temperament could also be misleading since this has never been a practical keyboard temperament; just intonation might be a better term here.

In his book on Sweelinck's keyboard music, Alan Curtis attempts a solution to the problem of sixteenth and seventeenth century keyboard

(15) Walker, Ernest. A History of Music in England. 3rd edition. Oxford 1952. p.142.

(16) Walker, Ernest. Ibid. p.391.

temperaments. His whole section on temperament is too long to quote verbatim, but he starts by assuming that keyboards of the period were:

generally tuned in some form of meantone temperament. (17)

The vagueness implied by the words 'some form of meantone temperament' is a necessity at this early stage of his argument, for he is to elaborate on this later.

On the subject of retuning for different pieces, Alan Curtis writes:

Enharmonic tones in different pieces could easily be accommodated by retuning, or by performance on different instruments. For a performance on stringed keyboard instruments, the D sharps required for one piece could quickly and easily be changed to the E flats needed for another, and vice versa - as they undoubtedly were even into the eighteenth century. (18)

On this point he is immediately at variance with the views expressed by Charles van den Borren quoted earlier (page 13).

Curtis goes on from here:

But the presence of enharmonic tones in literature for the organ, as well as within the same piece, can only be explained by one of the following possibilities:  
1. a harshly out-of-tune note was tolerated occasionally, in passing, i.e. an E flat could function temporarily as a (sharp) D sharp; 2. the work was intended for an instrument with split keys, i.e. the accidental between D and E would be divided, one half operating a string or pipe sounding D sharp, the other half E flat, forming acoustically perfect thirds with the tones B and G respectively; 3. some form of equal temperament was applied to keyboard instruments, at least for chromatic pieces; 4. some modification of meantone tuning was employed, as for instance the irregular system of Arnelt Schlick. (19)

He then goes on to elaborate some of these proposals but comes down in favour of the fourth. It now becomes obvious why he chose the expression 'some form of meantone temperament' earlier in his exposition, because he later refers to two theorists who proposed modifications to meantone, Arnelt Schlick, in the passage quoted, and Werckmeister. It is one or other of the possible modifications to meantone which he suggests may have been used for the more highly chromatic pieces.

(17) Curtis, Alan. Sweelinck's Keyboard Music. London 1969. p.143  
(18) Curtis, Alan. Ibid. p.145.  
(19) Curtis, Alan. Ibid. pp.145/6.

The whole picture is very difficult to see through such mists of confusion which momentarily give a clear glimpse of this or that portion, but never allow the whole landscape to be revealed. Some of the confusions are caused because in none of the instances quoted is a complete 'scene' attempted. To do this, information about scales, intervals and temperaments used, the instruments available, and a close look at the keyboard music in question needs to be collected in one study, in the hope that some useful summary of the situation can be attempted.

## CHAPTER 3.

THE INSTRUMENTS.

A detailed history of the keyboard instruments in use in England during the late sixteenth and early seventeenth centuries would be inappropriate, but, for a variety of reasons, a brief description of the most important as well as the most unusual of them is necessary if only to clarify such misleading definitions as, "the clavichord was a sort of spinet resembling the virginals." (1)

Apart from the organ, the keyboard instruments in common use were the spinet, the virginal (or virginals), the clavichord and the harpsichord. (2) The word virginals or a variant of it would probably be used in England up to about 1650 to mean harpsichord as well as the smaller instruments we now usually call virginals. Large instruments were in use in England, no matter what they were called, as surviving instruments and the title page of Parthenia Inviolata show. An early reference appears in the Privy Purse expenses of Henry the Eighth in 1530:

(April) Item the vj daye paied to William Lewes for ij payer of virginalls in one ceffer with iiij stoppes brought to Greenewiche iiij li ..... and for ii payres of virginalls in one ceffer brought to the More other iii li. (3)

Raymond Russell says of this entry, "this appears to have been a double harpsichord with four stops. 1530 is very early for such an instrument ....., but no other meaning for the entry seems possible." (4)

Even though the word virginals was used indiscriminately for keyboard instruments, it must sometimes be taken literally. For instance, at the time of the Fire of London, Samuel Pepys wrote:

River full of lighters and boats taking in goods, and good goods swimming in the water; and only I observed that hardly one lighter in three that had the goods of a house in, but there was a pair of Virginalls in it. (5)

Although some of the instruments might have been harpsichords, it is likely that most of them were virginals, because Pepys does also use the words harpsichord and spinet:

1. Grove's Dictionary of Music and Musicians. 5th Edition. London 1954. Article on Virginals, quoting Roscoe 1823.
2. The present discussion is limited to the plucked instruments, which are more often associated with the repertory under discussion.
3. Grove's Dictionary of Music and Musicians. 4th Edition. London 1940. Article on Harpsichord.
4. Russell, Raymond. The Harpsichord and Clavichord. London. 1959.
5. Pepys, Samuel. Diary. Entry for 2nd September 1666.

Thence all my people to Deptford to see Balty, while I to buy my espinette, which I did now agree for, and did at Howard's meet with Mr. Thacker, and heard him play on the harpsichon, so as I never heard man before I think. (5)

Virginals were domestic instruments and more likely to be found among the other household chattels being moved out of the path of the fire than the larger harpsichord, although spinets and clavichords would also have been used in houses and could have appeared on the lighters and boats. It is unlikely that Pepys would have confused the instruments by their outside shape, except perhaps virginals and clavichords which are both rectangular, but the virginals would generally be the larger instruments.

Since there was such confusion over the use of the words, the description "English virginalists" and the titles Fitzwilliam Virginal Book and Ben Cosyns Virginal Book are equally suspect. They would be more correctly referred to as "English keyboard players" or "Ben Cosyns book of keyboard music". This has some significance in the study of temperament since the instruments are different and some would be more likely kept in good tune than others. If the virginals was the "upright piano" of the day, as Raymond Russell suggests (6), we could expect that many of them would suffer a similar fate as their modern counterparts so far as tuning is concerned. Harpsichords being bigger and more expensive, might well have been kept in better tune and, because of their size, moved less frequently. They might also have been kept in tune by tuners more versed in any "modern" methods of tempering.

The word virginals now usually means the rectangular or pentagonal instrument in which the strings lie parallel to the keyboard, and pass over two bridges both of which are on the sounding board. The instruments vary in size, but are not particularly small. There are surviving examples of double virginals in some of which the two keyboards are fixed in position (7), but in others, the smaller, octave, instrument would be carried inside the case of the larger but removed for playing (8). The action is similar to that of the harpsichord, but more than one string for each key is rare.

(5) Pepys, Samuel. Diary. Entry for 13th July 1668.

(6) Russell, Raymond. Op cit. p.21

(7) Ibid. Illustration No.20

(8) Ibid. Illustration No.29



The spinet also has the same type of plucking mechanism as the harpsichord, but is always a wing shaped instrument. The strings run off at an angle to the keyboard but only one bridge is on the sounding board; the other is on the wrest plank. More than one string to a note is not common, but Mersenne describes a spinet with a variety of stops:

And the first common stop, which is the basis of the others, can be called the fundamental stop, to which is sometimes added a similar stop at the unison and another at the octave, so as to render the harmony fuller, and so that it can have a greater effect in the concerts and on the listeners. One can add further another stop of the third of the fifth, some of which will be able to have lute strings and others brass or steel. These are all the stops that have been used to the present, which are called the double or triple spinet. (9)

This description fits a harpsichord better than a spinet, but the French 'espinette' is more correctly translated as spinet or virginals than as harpsichord, which would be 'clavecin'.

The clavichord differs entirely from the other instruments. The strings are struck by metal blades or tangents, not plucked by quills or leather plectra. The resultant sound is much softer, but can be graded in intensity within the restricted dynamic range of the instrument, and since the tangent can be kept in contact with the string, a vibrato (bebung) is possible which is not available on the other string keyboard instruments. The clavichord is the smallest in size except for the octave type of spinets and virginals, and it gives the smallest sound.

The harpsichord was the largest of the stringed keyboard instruments and capable of the greatest variety in sound. It usually had one or two keyboards and a variety of stops to alter both pitch and quality. Larger instruments with three manuals were also made, but the only reference to an English instrument of this size is later (1774) and the instrument itself has not survived. There is a three manual instrument in the Russell Collection at Edinburgh University made by S. Belcioni in 1627. The manuals, bottom to top, are 8', 8' and 4'; the instrument is believed to be of French origin.

Some two manual instruments were designed to facilitate the transposition of accompaniments by a fourth or fifth. Many of these instruments have been altered, but one, at least, remains fairly well intact and again is in the Russell Collection. This harpsichord was

(9) Mersenne, Marin. Harmonie Universelle (1635).  
Trans. Chapman. The Hague. 1957.

built by Jan Ruckers in 1638. The upper manual range is from C/E - c<sup>3</sup> (45 notes) and the lower manual C/E - f<sup>3</sup> (50 notes). The keys are so aligned that F - f<sup>3</sup> on the lower manual play the same strings as the upper manual keys C - c<sup>3</sup>. Five extra sets of strings are provided for the remaining lower manual keys. This instrument has two wrest pins set close together for the E flats. Of this arrangement Raymond Russell wrote:

One more original feature of the harpsichords built in the Ruckers workshops must be mentioned; this was a very primitive attempt to get rid of the 'wolf' - the interval which in meantone tuning was aggressively out of tune. This interval was usually A flat - E flat, and for each E flat the Ruckers provided two strings on both the eight and the four foot stops. These two strings ran, almost touching, over the nut, were plucked together by one jack, and were hitched together on the hitchpin rail. Signs of them can often be detected at these points and also at the tuning pins. The Ruckers always arranged the pins in two straight lines, one for the eight foot and one for the four foot, and at the E flats a second pin standing forward from the first will often show where this crude system was in use. Van Blanckenburg (1739) tells us that Francisco de Salinas recommended quarter tones for keys E flat and D flat, and says 'I have seen several large organs and clavecins of Ruckers with these additions .....' (10)

Further investigation has uncovered the true reason for these extra strings. The lower manual G sharp on the transposing instruments is in alignment with the upper manual E flat. In meantone tuning the E flat would be too sharp to give the correct note on the lower manual, and another string tuned to D sharp is required (sounding as a true G sharp on the lower manual). The strings were not sounded together as Raymond Russell suggested, and it is an ingenious, far from primitive device for keeping the 'wolf' in the proper place on each manual.

To extend the sounding compass of the keyboard, two short octave bass systems were in common use. Since the lower accidentals were required less frequently, the last few notes of the instrument were tuned to diatonic notes only. Such a keyboard might look as though it ran from E - d<sup>3</sup>, but, in fact, the low E would be tuned to sound C, the F sharp to sound D, G sharp to sound E, the F and G would sound normally and the chromatic scale would begin on A. Many early instruments show BB as the lowest note. This was tuned to sound GG, C sharp to sound AA, D sharp to sound BB, C and D would be correctly tuned and the chromatic scale would begin on E. To gain the best of both worlds the other

(10) Russell, Raymond. The Harpsichord and Clavichord.  
London 1959. p.46.

system divided the two lowest accidentals, C sharp and D sharp or F sharp and G sharp, into two independent keys. The back part of the key was then tuned to the correct notes and the front part to the short octave. This latter system was sometimes known as the broken octave to distinguish it from the more common short octave.

As well as the orthodox instruments just referred to, there were many attempts to make keyboard instruments with more than twelve different keys to the octave, because as Mersenne says, 'the keyboard of thirteen keys to the octave [he includes the starting note at top and bottom] cannot have all the just consonances, whatever disposition can be given them.' (11) He advocates a 'perfect harmonic keyboard with nineteen keys to the octave.' Such a keyboard would have a split key for D and two notes where our single black notes would be, making ten black notes and nine white (as the starting note was repeated, there were only eighteen different notes). He also shows possible keyboards with twenty-seven and thirty-two keys to the octave.

In music, as in other aspects of life, the Renaissance meant the rebirth of interest in the classical world. It meant the rediscovery of ancient theories, and attempts to put some of these theories into practice. The Florentine camerata began by trying to revive Greek drama. As it eventually turned out they set musicians on the path to opera. Other revivals bore less fruit and the attempts to construct instruments to play in the three Greek genera, diatonic, chromatic and enharmonic, fall into this category. Nevertheless, instruments were made and would have been played upon, which means that the music played must either have been composed for the instruments or altered in sound by being played on them. That these instruments did not find general favour among musicians is borne out by some of the following quotations, but descriptions of the instruments are precise and at least one is still in existence.

Vite Transuntine, an early seventeenth century instrument maker, produced a four octave harpsichord on which each accidental is divided into four keys and an extra key, divided into two parts, is provided between each of the natural key semitones, making thirty-two keys to each octave, and one hundred and twenty-five on the keyboard as a whole. This instrument was inspired by the composer and theorist Nicola Vicentine who suggested a keyboard to include the three Greek genera (12).

(11) Mersenne, Marin. Harmonie Universelle (1635)  
Trans. Chapman. The Hague. 1957. p.434.

(12) Vicentine, Nicola. L'Antica Musica Ridotta alla Moderna Pratica. Rome 1555.

25.

A photograph of this instrument appears in Russell (13). It is a single manual instrument with one eight foot register and one set of jacks. Another instrument described by Vicentine (14), also capable of playing all the notes of the three genera, had six manuals with thirty-one keys to the octave.

Two instruments are mentioned by Martine Pesenti (15). One built by Domenico de Pesare in 1548 had twenty-four keys to the octave, the other built by Vite Transuntine had twenty-eight keys to the octave (16).

Grove's Dictionary of Music and Musicians refers to an enharmonic instrument made for Zarline.— The maker is named as Domenice Pesarese, so this may have been the instrument mentioned above. Grove's Dictionary goes on to say that Burney went to see an instrument with enharmonic notes made for Zarline at Venice (possibly the same instrument again), when it was in the possession of Pescetti's widow, Signora Mencini, and he declared that 'the mechanism and tone were so bad, that no tuning could render its sound agreeable'. This instrument was eventually sent over to England. Burney also says:

I copied Zarline's instructions for tuning it, from his own handwriting, on the back of the foreboard; but I shall reserve them, and the particular description of this curious instrument, for the History of Music, to which they more properly belong. (17)

It is unfortunate that his History of Music does not fulfil the promise given above, nor is there any verification of the statement that the instrument found its way to England.

There is, however, verification for an enharmonic instrument made and/or owned by Charles Luythen.

A simplified instrument of greater practical importance built by the Belgian Charles Luythen (1556 - 1620). It had eighteen keys to the octave, namely in addition to the diatonic notes C sharp and D flat, D sharp and E flat, F sharp and G flat, G sharp and A flat, B flat, E sharp and B sharp. This instrument is called "Clavicymbalum Universale" (M. Praetorius in his Syntagma Musicum Vol.2, 1618, praises it

- (13) Russell, Raymond. Op. cit. Plate 13.
- (14) Vicentine, Nicola. Op.cit. and Descrizione dell Arciorgano. 1561.
- (15) Pesenti, Martine. Preface to Correnti, gagliardi e Ballei ..... libro quarto. 1645.
- (16) Grove's Dictionary of Music and Musicians. 5th edition Article on Enharmonic Harpsichords.
- (17) Burney. The Present State of Music in France and Italy. London. 1771.

as 'instrumentum perfectum si non perfectissimum'), permitted enharmonic change and modulation in all keys without the compromise of equal temperament. (18)

The existence of such an instrument is mentioned in Greve's Dictionary of Music and Musicians (19) but some of the facts differ from those above. Charles Luythen was born in Antwerp about 1556, spent most of his life in the service of the Imperial Court at Vienna and Prague, and died in Prague in 1620. Praetorius had seen in his possession at Prague a 'clavicymbalum' manufactured in Vienna, on which different keys were provided for two distinct semitones between each whole tone to ensure pure major thirds and to allow the transposition of the Church modes on any key. Two keys were inserted between the semitones E - F and B - C for enharmonic modulation, and the four octave keyboard C - c<sup>3</sup> contained seventy-seven keys.

We learn that Luythen's pension, granted in 1611, was contested in 1612 when Rudolph II, who granted it, died. The arrears were never paid. In 1613 he was obliged to sell his harpsichord. It is not stated whether this was the 'clavicymbalum' or just an ordinary instrument. He died, unmarried, in 1620 and the heirs to his estate were his brother, Claude, a teacher in Antwerp, and his sisters Clara and Sibilla. If the estate still included the 'clavicymbalum' there is no clear evidence whether this instrument came into his heirs' possession in Antwerp or was sold in Prague.

Sir Jehn Hawkins makes several references to enharmonic instruments. Although his history dates from the eighteenth century, his corroboration of some of the facts is helpful. Of greater interest are his reports on how the instruments were viewed by his predecessors and contemporaries:

..... Galeazzo Sabbatini of Mirandola, made a bold effort and gave a division of the Abacus or keyboard, by means whereof he proposed to exhibit all imaginable harmonies, but it seems that none of these divisions were ever received into practice ..... One Nicolaus Ramarinus, in the year 1640, invented a keyboard simple in its division, but changeable by means of registers..... but neither was this contrivance adopted .....

..... Gio Battista Doni, in his treatise De Genera e de' Modi della Musica, cap. I. pretends to point out how many absurdities in his [Vicentine's] division of the tetrachord for the purpose of introducing the ancient genera into modern

(18) Apel, Willi. Harvard Dictionary of Music. 2nd Edition. London 1970. Article on Archicembalum.

(19) Greve's Dictionary of Music and Musicians. 5th Edition. Article on Karel Luythen.

practice, and treats his invention of the Archicembale with great contempt ..... And as touching that division of the octave by Vincentino which Doni and others are said to have improved, the late Dr. Pepusch is clearly of the opinion that it was perfectly agreeable to the doctrines of the ancients ..... (20)

Hawkins takes up the subject again later when writing about Salinas:

In the thirteenth and subsequent chapters of his third book, Salinas treats of the temperament of the organ and other instruments. He says of the human voice that it is flexible..... but in the organ and other instruments where the sounds are fixed and are not determined by the touch of the performer, he says that the tones are of necessity equal, and that this equality is preserved by the distribution of the three commas, by which the three greater tones in the diapason exceed the lesser ones, so that by this distribution, the consonances and lesser intervals participate of that dissonance which in some part of the system or other is occasioned by the comma.

The system thus attempted is called by the Italians Systema Participate.....

The fertility of Salinas's invention suggested to him other temperaments which he described with his usual accuracy. After stating and comparing them, and giving the preference to the first he proceeds in chap. xxvii to show the bad constitution of a certain instrument begun to be constructed in Italy about forty years before the time of writing his book, that is to say, about the year 1537, concerning which he says that this instrument was called the Archicembalum, and that it divided each of the tones into five parts..... He says that as the diapason contains six tones and a diesis, it divided the octave into thirty-one parts but that they are diesis he absolutely denies. He then proceeds to point out the defects of this instrument, and pronounces of it, that it was offensive to his ear, and was not constructed in any truly harmonical ratio. (21)

Another reference in Hawkins appears when he is discussing Bettrigaro (Hercule Bettrigaro) 'the author' in the passage below and his book Il desiderio ouvere de concerti di varii stromenti musicale published in 1594:

After this general account of the instruments, the author mentions certain others which he himself saw at the palace of the duke [at Ferrara], and were there preserved for their antiquity, and others in respect of the singularity of their construction; among these he takes notice of a curious organ, formed to the resemblance of a screw,

(20) Hawkins, Sir John. A General History of the Science and Practice of Music. Reprint by Dover New York

1963. p. 395-6.

(21) Ibid. p. 415-6.

with pipes of box-wood all of one piece like a flute; and a harpsichord invented by Don Nicola Vicentino surnamed Arcimusice, comprehending harmonic genera. He adds that the multitude of chords in this astonishing instrument rendered it very difficult to tune, and more so to play; and that for this reason the most skilful performers would seldom care to meddle with it; nevertheless, he adds, that Luzzasco, the chief organist of his highness, who it is supposed must have understood and been familiar with the instrument, was able to play on it with wonderful skill. He says that this instrument by way of pre-eminence was called the Archicembale; and that after the model of it two organs were built, the one at Rome, by the order of the Cardinal of Ferrara, and the other at Milan, under the direction of the inventor Don Nicola, in or about the year 1575, who died of the plague soon after it was finished. (22)

One final detail about the instruments which has some bearing on temperament remains to be described. Since the 'wolf' interval in meantone tuning is the apparent fifth, G sharp to E flat, efforts have been made to alter these two notes only. Some organ builders were prompted to provide two more pipes to the octave for each step to give G sharp as well as A flat and D sharp as well as E flat. To accomplish this the appropriate keys were divided, the front half of the key giving one note and the back half the other. This device was adopted as early as the sixteenth century, because Salinas records that he found it on an organ in Florence. Father Smith went half way when he built the Temple Church organ in 1684 and divided the G sharp key in the middle, raised the back half of it and tuned it to A flat.

Such additions to keyboards did not meet with much success and we find Roger North writing:

Some experiments have bin made, by more additional pipes which they call Quarter Notes, to gain a perfection of the tune; but ever and besides the increase of charge and incumbrance in the fabrick (sufficient discouragement), they find it will not by any means be obtained to answer all the scales as may be required. Therefore the nicety is dropped and the masters are contented. (23)

This view was endorsed by Robert Smith when he wrote, 'The old expedient of introducing some of these sounds (D sharp, A sharp, A flat, D flat, G flat etc.) by inserting more keys in every octave is quite laid aside by reason of the difficulty of playing upon them.' (24)

- (22) Hawkins, Sir John. A General History of the Science and Practice of Music. Reprint Dover New York 1963. p. 446.  
 (23) North, Roger. Theory of Sounds. London 1726.  
 (24) Smith, Robert. Harmonics. London (?) 1759.

Harpsichords as well as organs were made with divided keys. An instrument owned by the Brussels Conservatoire, made in 1619 by Boni of Cortona, has each G sharp and E flat divided. The lowest octave of the instrument is short and the F sharp and G sharp are divided to give D and E at the front and a chromatic sequence at the back. On the rest of the keyboard each E flat is divided to give D sharp at the front and E flat at the back. Similarly each G sharp key gives G sharp at the front and A flat at the back. Details of some other Italian instruments with split keys are given by Frank Hubbard (25). Those mentioned date from 1601 to 1711 and are only some of the instruments which have survived. Two of the instruments are by Boni, of whom Mersenne remarked that he made good harpsichords with split keys that one could tune perfectly. There is no evidence that English harpsichords had such devices; the split keys which occur are concerned with the short bass systems previously described.

The foregoing descriptions have been presented with very little attempt either to follow up obvious implications for particular pieces or to draw conclusions about the temperament in general. Such considerations have been left for a later time when dealing with the music in more detail, because the music must ultimately be the deciding factor. The instruments, except for those with a large number of keys to the octave, could have been tuned in many different ways. Twelve notes to the octave could mean any of the regular meantone tunings, many irregular tunings and equal temperament. It seems likely that since many more theories about how an instrument should be tuned were being discussed than would now be considered, some of them might well have been put into practice. It seems equally likely that although there were enharmonic instruments, most keyboards contained the usual twelve notes to the octave. Some of the extracts above suggest that musicians were cautious in their approach to these novelties because of the difficulties presented in tuning and performing on the instruments as well as the increased cost and size. Unless the tuners were an army of revolutionaries some standard system of tuning would be accepted and deviation from this would only be for special purposes.

The tuning of a stringed keyboard instrument would probably be well within the abilities of most composers of the day, but whether or not

(25) Hubbard, Frank. Three Centuries of Harpsichord Making.  
Cambridge, Massachusetts. 1965. p.36.



they practised this particular ability is not documented. Practical musicians are often sceptical of the theorists and learn more from the written music of their fellows than from reading. It is unfortunate that the written music does not always carry with it the exact specifications of the temperament. Keyboard players are more likely to play other people's music on the temperament to which they themselves are accustomed rather than make enquiries about any variations intended unless the written notes demand such enquiry. In this way, ideas about form and figuration would be disseminated much more widely among musicians than would slight fluctuations of temperament. There is all the more reason then to make use of the few facts that the music does reveal, to tell us about temperament and study them with some care.

## CHAPTER 4.

SCALES, INTERVALS AND TEMPERAMENTS.

"If we tune upwards from any given note in a series of octaves, perfect fifths or true major thirds, we never reach a unison again between the notes of any two of the series however far we go". (1) Any attempt therefore to fit true fifths, thirds and octaves together into a fixed temperament is doomed to failure. The discrepancies which will result in any such attempt are as follows: four perfect fifths exceed two octaves and a true major third by a comma (the comma of Didymus, or, more commonly, a syntonic comma): twelve perfect fifths exceed seven octaves by the comma of Pythagoras: eight perfect fifths and a major third exceeds five octaves by a schisma: one octave exceeds three true major thirds by a diesis. To give some idea of the size of these intervals, there are eleven schismas in a syntonic comma, twelve in a comma of Pythagoras, and twenty-one in a diesis. A diesis is slightly more than one fifth of a whole tone. In the performance of music these discrepancies must be eliminated and it is their elimination which we know as tempering.

All music needs to be tempered, but when we refer to temperament we usually mean some sort of division of the octave into twelve notes suitable for use on a keyboard. A scale, being a succession of notes, is dependent on the type of temperament selected. In vocal music, and on instruments which have the freedom to alter pitch fractionally at will, scales can be changeable, but on a keyboard where the tuning is a compromise between that which is desirable and that which is tolerable, the note relationships in a scale are frozen into a solid form in the act of tuning and cannot be altered in performance. They cannot even be drastically altered between items in a performance because of the length of time involved in tuning and the undesirability of the interruption.

The sentence which opened the last paragraph needs some qualification. Temperament is a harmonic rather than a melodic necessity, because there can be no question of dissonance between notes played consecutively. It was Helmholtz (2) who first offered an explanation of the nature of dissonance. The effect of notes beating when nearly

(1) Lloyd, L.S. Intervals, Scales and Temperaments. London 1963.

(2) Helmholtz, H. On the Sensation of Tone. Trans. 1885 by A.J. Ellis.

approaching each other in pitch but not exactly in tune with each other, and the dramatic difference which is evident when the notes do coincide exactly, were known long before Helmholtz but he it was who first explained that dissonance between two notes at some distance from each other was caused by beating between the respective harmonics of the notes concerned. The reason for this can be seen from Example 1:

Example 1.



The semibreves, in the above example, refer to the notes to be sounded together, the crotchets refer to the harmonics of these notes. In each case the harmonics are continued far enough to reach a unison.

If the octave or fifth is mistuned, the unisons between the harmonics will be mistuned and they will beat. Since the lower harmonics are more powerful, the beating will be more noticeable with the octave and fifth than with the third and sixth. In the latter two intervals, the disturbed unison would be between fainter harmonics. We would be less conscious of mistuning between thirds and sixths therefore than we would of the mistuning of octaves and fifths. For this reason octaves and fifths are said to be sharply defined.

Added to this, the thirds and sixths each have a pair of harmonics a semitone or a tone apart. These harmonics too will produce beats which will further obscure the beating of the fainter mistuned unison. Imperfect concords have vaguer outlines than perfect concords, while the outlines of discords are even more vague. This, as L.S. Lloyd says (3), is perhaps the explanation of the 'perfectness' of a perfect interval. It is also the reason for the fifth (and its inversion, the fourth) being of such fundamental importance in tuning keyboard instruments.

(3) Lloyd, L.S. Intervals, Scales and Temperaments.  
London 1963. p.13.

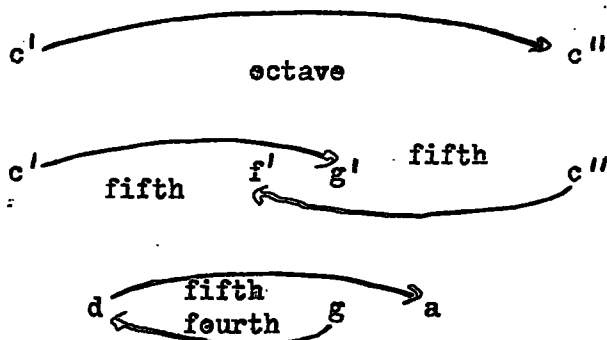
Scales are the result of general usage. As Sir Hubert Parry says: "Scales are made in the process of endeavouring to make music and continue to be altered and modified, generation after generation even till the art has arrived at a high degree of maturity" (4). W.C. Sabine attributes the origin of the scale to the harmonics contained in single notes. He builds his theory, which formed his Vice-Presidential Address to the American Association for the Advancement of Science, Chicago, in 1907, on the facts of reverberation. Taking as his starting point the fact that the musical scale we use grew up among dwellers in stone buildings, from caves to cathedrals, he points out that sounds made in succession in such buildings do not remain in isolation, but merge to form chords. The beating caused by dissonances would tend to make the notes chosen to follow each other in succession those which would give the best chords. Whether this is the true explanation or not, the fact remains that the basic notes of the scale form the tonic, dominant and sub-dominant chords, or, in other words, the chords formed on notes most closely associated to each other in the harmonic series.

The eight note diatonic scale so formed was the material of the Church modes. Depending on which note one begins, so the position of the semitones will change. Musical theory from the time of Guido of Arezzo was based on the hexachord rather than the full diatonic scale. Hexachords beginning on C and G (hexachordum naturale and hexachordum durum) would be correct using only the notes of the diatonic scale, but the hexachord which begins on F (hexachordum molle) would need to have its fourth note flattened to make the run of notes the same as in the other two hexachords. If these were to be the only notes required, a keyboard needs just the white notes and a B flat. Such keyboards did exist, and as late as 1619 Michael Praetorius (5) makes mention of them. In practice, because of the transposition of modes and the licences permitted by musica ficta, more notes were required, and keyboards were extended to give all the diatonic notes and the permitted accidentals of modal practice. The keyboard so formed is the one we still use. The difference is that the notes on the keyboard, because of the constantly changing nature of their functions over the years, have been subjected to various methods of tuning.

(4) Parry, Sir C.H.H. The Art of Music. London 1896.

(5) Praetorius, M. Syntagma Musicum. Wolfenbuttel 1619.

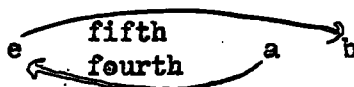
Using fifths, fourths and octaves only from a given note (let us say  $c'$ ), one of the simplest scales to produce would be the pentatonic scale. It could be tuned as follows:



so the notes produced would be

$c \quad d \quad f \quad g \quad a \quad c$

The other two notes to complete the alphabetic sequence could easily be tuned:



If all the intervals used for tuning were exactly true, the frequency ratios for each note would be:

$c$	$d$	$f$	$g$	$a$	$c$
1	$\frac{9}{8}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{27}{16}$	2

and for the complete scale:

$c$	$d$	$e$	$f$	$g$	$a$	$b$	$c$	
1	$\frac{9}{8}$	$\frac{81}{64}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{27}{16}$	$\frac{243}{128}$	2	(frequency)
	$\frac{9}{8}$	$\frac{9}{8}$	$\frac{256}{243}$	$\frac{9}{8}$	$\frac{9}{8}$	$\frac{9}{8}$	$\frac{256}{243}$	(interval)

The second row of ratios, which represent the intervals, reveals a consistency in the tones and semitones of the white notes of a keyboard. The resultant scale is the Pythagorean diatonic scale, the interval with ratio  $9 : 8$  is the Pythagorean whole tone and the interval with the ratio  $256 : 243$  is the Pythagorean diatonic semitone.

If this method of tuning is carried on into the tuning of the black notes of a keyboard, the note  $f'$  sharp, a fourth below  $b'$  would be represented by the ratio  $750 : 512$ , making the interval  $f'$  sharp to  $g'$  a Pythagorean semitone (ratio  $256 : 243$ ) as before. The  $f'$  to  $f'$  sharp interval, however, would be in the ratio  $2187 : 2048$ ; this is a Pythagorean chromatic semitone and is slightly larger than the diatonic semitone.

This is not the only difficulty. If the system of tuning is continued until b' sharp (the enharmonic equivalent of c'') is reached, the interval between these notes would be in the ratio 531441 : 524288. This means that the b' sharp would be higher than the c'' by a small interval which is known as the comma of Pythagoras.

If this scale, either in its chromatic or its diatonic form, is used for music in which chords are necessary, the major thirds of the chords will be sharper than true and the minor thirds flatter than true.

Considering thirds more closely, three main types can be isolated; true thirds, consistently tempered thirds and inconsistently tempered thirds. The first category is self evident, the second is that into which the thirds in a regular temperament (e.g. equal temperament, or Pythagorean temperament) would be placed, and the third category would include thirds which vary throughout the temperament, such as those which would be produced by one of the irregular temperaments described by Werckmeister, and thirds which form passing notes in music played by instruments with flexible pitch.

A true major third is formed between two notes when the fifth harmonic of one is in unison with the fourth harmonic of the other. Since it is a less sharply defined interval than the fifth or octave, it is more difficult for the musician to 'hear' it in tune. The beating between the fourth harmonic of the lower note and the third harmonic of the upper note is part of the reason for this since they are closer to the fundamental note than the harmonic which should be in unison. Even so, the 'stillness' of an in tune major third can readily be recognised.

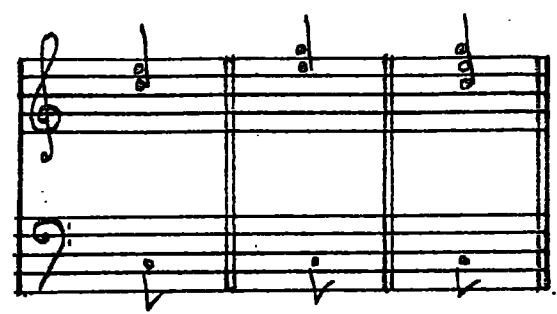
The most likely major thirds to be found in the second category are those which would be produced by a Pythagorean or by equal temperament. The major third of equal temperament is a wider interval than a true major third. It is arrived at by tuning all fifths flat by one twelfth of a Pythagorean comma to allow for that comma's disappearance over a series of twelve fifths and so make that series fit exactly into seven octaves. This third is a by-product of the temperament and its sharpness is so noticeable that piano tuners often refer to it as a 'running' third because the beating is so obvious. A Pythagorean third is also the by-product of the temperament, and is even sharper than the equal tempered major third. Although it is acceptable melodically, and, in fact, is often preferred by violinist, it suffers harmonically from the same defects as any other mistuned third, as will be explained later.

The third category can be subdivided. The first subdivision includes thirds produced by an irregular temperament. In an irregular temperament, the amount of alteration to each interval varies in different keys. For instance, the major third between c and e would likely be sharper than true, but not as sharp as an equally tempered major third, whilst the third d flat to f would be sharper than an equal tempered third. In this way some of the more frequently used major thirds would be kept nearer to true than their equally tempered counterparts would be, but the less used major thirds would be worse, although all would be tolerable.

The second subdivision would include thirds made between parts by instruments with flexible pitch. In this case the width of the third produced would depend on the context. If one of the notes forming the third happened to be the leading note of the melodic part in which it appeared and was also the upper note of the third, it would be sharpened and widen the third; if, however, it happened to be the lower note, the sharpening would have the effect of narrowing the third. It would depend solely on the performer whether he thought the harmonic or the melodic interest was the more important in the circumstances.

Since a major third lacks the definition of a fifth or an octave, it could be argued that mistuning it would be less objectionable from a musical point of view. If the definition of the interval was all that mattered this would be so, but more important than the definition is the difference tone formed by the two notes. This is created by the asymmetrical construction of our ears, and is formed from the difference between the frequencies of the two notes sounded. It is a pure tone and so will not have harmonics. The difference tones formed by both major and minor thirds which make up the triad of C major are as follows:

Example 2.

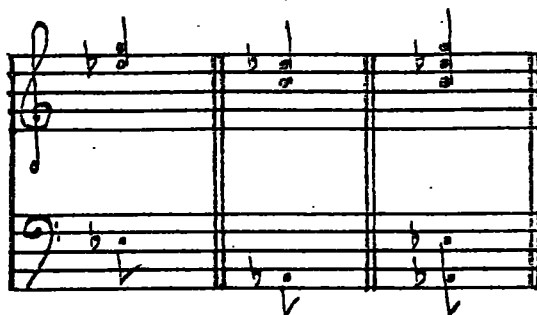


The difference tones at 1 and 2 above are produced by the thirds shown. If the triad is correctly tuned, it too must produce the same difference tone. If the thirds are mistuned the resultant difference tones will alter, becoming sharper or flatter depending on the amount and direction of the mistuning.

Looking more closely at the triad at 3 above, if the major third is sharpened we can deduce from 1 and 2 that the difference tone at 1 would rise and that at 2 would fall. Since the two difference tones so produced would be close in pitch they would beat. Added to this, the harmonics of each of the thirds themselves, which should be in unison, would not be so, and would also beat, causing a considerable amount of dissonance. It is the harmonic use of a mistuned major third which makes the interval objectionable.

The minor triad is different. The difference tones produced by it are shown below.

Example 3.



In this case, the difference tones are so far apart that no mistuning of the interval could make them beat. Since they are pure tones, the fifth between them would not beat if it were mistuned because such beating in a fifth would depend on the harmonics of the notes concerned and not the fundamental notes.

A quotation from Helmholtz on thirds sums up the situation.

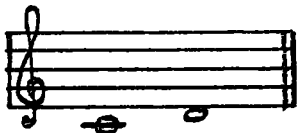
For the Pythagorean thirds  $c' - e'$  and  $e' - g'$ , the combination tones are nearly C sharp and B, both differing by a semitone from the combination tone C, which would result from the perfect intervals in both cases. For the Pythagorean minor chord  $e' - g' - b'$  the combination tones are B, and very nearly G sharp. The first, B, is very suitable, better even than the combination tone C which results from perfect intonation. But the second, G sharp, belongs to the major and not the minor chord of E. However, as in perfect intonation one of the two combination



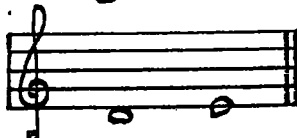
tones C and G is false, the Pythagorean minor chord can hardly be considered inferior in this respect. But the combination tones of the equally tempered third lie between those of the perfect and Pythagorean thirds, and are less than a semitone different from those of just intonation. Hence they respond to no possible modulation, no tone of the chromatic scale, no dissonance that could possibly be introduced by the progression of the melody; they simply sound out of tune and wrong. (6)

The flexibility of scales in music for voices and instruments capable of making small adjustments in pitch, has been referred to by writers in different periods. The following quotation from C.V. Stanford, better known as a composer than a theorist, but here, perhaps, speaking in both capacities, describes the position accurately and in some detail.

The basis of the pure scale is that diatonic semitones are a fixed interval, and tones changeable. There is a greater tone and a lesser tone. In the pure scale of C the interval (a)



is slightly wider than the interval (b)

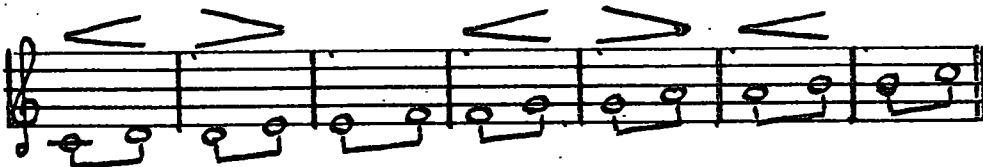


If the interval (a) were in perfect intonation and the same distance were to be applied to (b), the result would be a major third which was too wide, and the diatonic



semitone would be too small to satisfy the ear. The greater and lesser tones are alternatives in the scale.

If  $\angle$  equals the greater tone and  $\sphericalangle$  equals the lesser tone, the pure scale of C will be constituted thus:



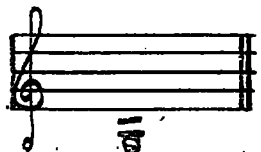
(The student is recommended to test the scale on a violin.)

The ratios of the intervals have been calculated out and are as follows:

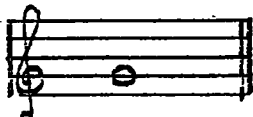
(6) Helmholtz, H. On the Sensations of Tone.  
Trans. 1885 by A.J. Ellis.

Diatonic semitone .....	15/16
Lesser tone .....	9/10
Greater tone .....	8/9
Major third .....	4/5
Perfect fourth .....	3/4
Perfect fifth .....	2/3
Major sixth .....	3/5
Major seventh .....	8/15
Octave .....	1/2

These can be verified on a violin with the aid of a yard measure.



e.g. if the G string equals 1



half the G string gives

the octave:

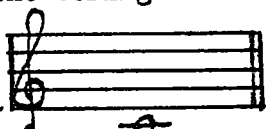
if 4/5 of the string lies between the finger and the bridge



the note will be

a major third from G; if

3/4 of the string lies between the finger and the bridge, the note



will be

a perfect fourth from G, and so on

throughout the scale.

When the harmonics are added to the notes of the scale of C, one note has to be liable to change and is termed 'mutable'. This note is D, the second degree, which must be a lesser tone from C (9/10) in order to combine with F and A (the supertonic triad), and the greater tone from C (8/9) in order to combine with G. This can be tested arithmetically by calculating the interval from C to F (3/4), the perfect fifth from D to A (2/3), and the major third from F to A (4/5), which will show that to

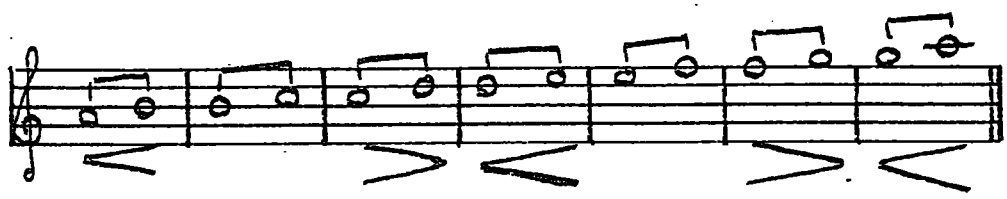


make the chord

perfectly in tune, the

interval from C to D must be 9/10 and from D to E 8/9. Similar investigation will show that to combine with G, D must be a greater tone (8/9) from C in order to make a perfect fourth (3/4) with G.

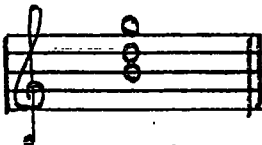
The minor scale is constituted thus:



The ratios of these intervals are as follows:

Lesser tone .....	9/10
Greater tone .....	8/9
Minor third .....	5/6
Perfect fourth .....	3/4
Perfect fifth .....	2/3
Minor sixth .....	5/8
Minor seventh .....	9/16
Octave .....	1/2

When harmonics are added to the scale, two notes are 'mutable', B, the second degree, and G, the seventh degree. B must be the lesser tone from A to combine with D, and G must be the lesser tone from F to combine with B and D



On the other hand, B must be the greater tone from A to combine with E, and G must be the greater tone from F to combine with B and E.



This can be similarly tested by applying the ratios for a minor third (B to D), minor sixth (B to G), and perfect fourth (D to G) in the first case; and by applying them for a perfect fourth (B to E), minor sixth (B to G), and minor third (E to G), in the second case. (7)

Stanford was not the first to comment on these phenomena. Marin Mersenne (8) agrees with the mutable D in the scale since it is the only white note he splits in his "perfect harmonic keyboard, with nineteen keys to the octave", giving major and minor tones above C, whilst Salinas, earlier still than Mersenne, agrees on the flexibility of the human voice, and Hawkins makes reference to his remarks (see page 19). A further reference to the flexibility of the voice and 'perfect instruments' (i.e. those capable of playing any notes, not just twelve to the octave), coupled with the need for tempering, occurs in the writings of Dr. Robert Smith, Master of Trinity College, Cambridge:

Mr. Huygens observed long ago, that no voice or perfect instrument can always proceed by perfect intervals, without erring from the pitch at first assumed. But as this would offend the ear of the musician, he naturally avoids it by his memory of pitch, or by tempering the intervals of the intermediate sound, so as to return to it again.

It is worth mentioning that both the eighteenth century writers, Hawkins and Smith, were referring to seventeenth century (Huygens) and sixteenth century (Salinas) writers, and Stanford made his observations with sixteenth century polyphony in mind. Musicians and musical

(7) Stanford, C.V. Musical Composition. London 1911.  
 (8) Mersenne, M. Harmonie Universelle. 1635. Tr. R.E. Chapman.  
 The Hague. 1957.

theorists were much more temperament conscious in the sixteenth and seventeenth centuries than they are now, and offered many different solutions to the problem. The facts are still the same, but we have only one solution, equal temperament, with the resultant tendency to ignore the flexible scale. The sixteenth and seventeenth century keyboard fact of twelve notes to the octave was, for the most part, the same as now, although there were attempts to make instruments with more than twelve notes to the octave, but, in tempering, the solution to it then was meantone tuning or some system akin to it.

Meantone temperament was first fully explained by Pietro Aaron (Thescanelle de la Musica 1523). The tuning is to be made in three successive stages, first the major third C to E is to be made "sonorous and just" and the fifth C to G made "a little flat". The fifth G to D is also flattened and then A is to be tuned so as to make the fifth D to A and the fifth A to E equal. In the second stage, the fifths F to C, B flat to F and E flat to B flat are tempered exactly the same as the diatonic fifths. Finally C sharp and F sharp are to be tuned as true thirds to A and D. Aaron says nothing about G sharp which probably also came in the final stage as a true third above E. The temperament described is quarter comma meantone temperament. Its name is derived from the division of the syntonic comma necessary to produce true major thirds. A major third is arrived at if four fifths are tuned in succession and then two octaves are subtracted i.e.  $c' - g' : g' - d'' : d'' - a'' : a'' - e'''$ , subtracting two octaves from  $e'''$  would bring us back to  $e'$ . If the fifths mentioned were tuned true the  $e'$  would be sharp by a syntonic comma. If the  $c' - e'$  interval is made true to begin the tuning, then the four fifths must each be tuned a quarter of a syntonic comma flat, hence quarter comma tuning. Aaron's first stage is to remove the syntonic comma by tuning four quarter comma flat fifths, his second stage is to tune the flat side of the key in quarter comma flat fifths as far as E flat and his third stage is to complete the twelve notes by tuning in true major thirds. Another method of setting the same scale is to tune in true major thirds as soon as the first stage is completed checking the resultant fifths against the first stage fifths to see if they are all equally flat. Whichever way the complete scale is set it should contain the following notes but not their enharmonic equivalents:

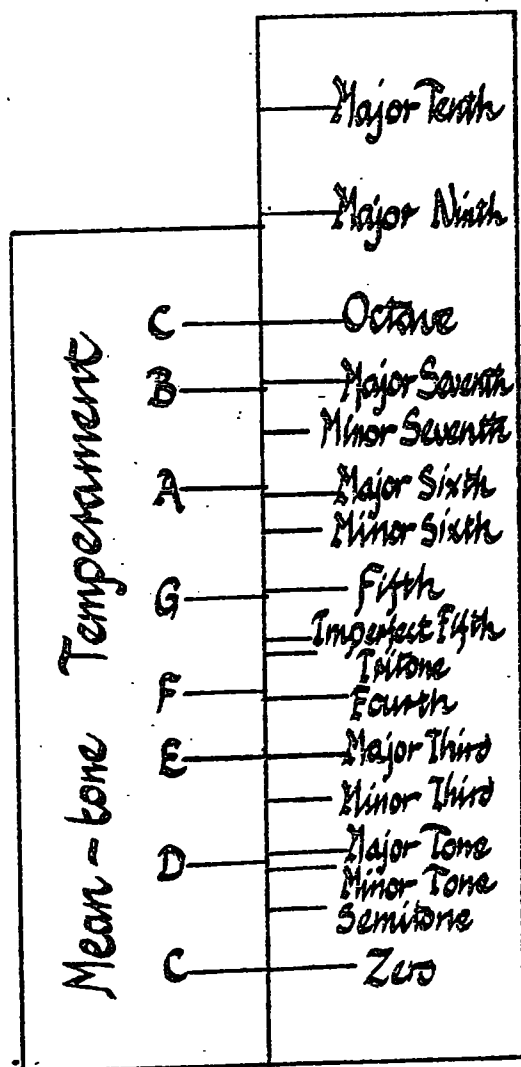
Example 4.



Because enharmonic equivalents are not available, only a limited number of keys can be used. They are C, G, D, A, F and B flat major, and G, D and A minor. More chords can be used than those suggested above, the complete list is: C, D, E flat, E, F, G, A and B flat major chords and C, C sharp, D, E, F sharp, G, A and B minor chords. Those which cannot be used are C sharp, F sharp, G sharp and B major and E flat, F, G sharp and B flat minor, plus, of course any common chords the keynote of which does not appear in Example 4. The serviceable minor keys, G, D and A, are very limiting and it was possibly the dearth of such keys which led some organ and harpsichord builders to provide split keys E flat/D sharp, G sharp/A flat and B flat/A sharp, which added C, E and B to the available minor keys and E, E flat and B to the major keys.

If other keys than those listed above are attempted, the 'wolves' begin to howl. To understand the reason for this we must again refer to true intervals. Between the notes f and g lie two accidentals, f sharp and g flat. The intervals f - g flat and f sharp - g are diatonic semitones, whilst that between f and g is a major tone. A major tone contains  $9\frac{1}{2}$  commas and each diatonic semitone 5.2 commas, the two semitones between f and g must, therefore, overlap by 0.9 commas. These figures assume the intervals to be just. In meantone temperament a meantone is half a comma less than a major tone, or 9 commas. On the other hand, a meantone semitone is a quarter comma larger than a diatonic semitone which makes it equivalent to 5.45 commas. The overlap in meantone between the intervals f - g flat and f sharp - g is now 1.9 commas, more than twice that for true intonation, which means that the meantone f sharp is flatter and the meantone g flat is sharper than true. The interval of 1.9 commas is more than one third of a diatonic semitone or nearly eight times the error of a meantone fifth. The amount of dissonance so produced when a note is substituted for its enharmonic equivalent is therefore considerable.

Fig. 1, taken from Intervals Scales and Temperaments, shows the intervals produced by meantone tuning on the left, and on the right are all the diatonic intervals up to a tenth shown with corresponding theoretical accuracy. The sizes of the intervals given on the right are those which they would have in appropriate concords of sixteenth century vocal music if sung perfectly in tune. A major third consists of a major tone and a minor tone, a fact which can be verified from the



..... FIG. 1.

above diagram. Since it is not possible to have both of these notes on a standard keyboard, however desirable they are harmonically, (Mersenne's "perfect harmonic keyboard with nineteen notes to the octave" makes it possible in a limited number of keys), the working compromise of splitting the difference between a major and a minor tone and calling it a meantone completes the derivation of the name quarter comma meantone temperament.

The scale produced by meantone tuning has slightly narrower whole tones and wider semitones than does the scale of equal temperament. When the scale is played, the 2nd, 3rd, 5th, 6th and 7th degrees sound flatter whilst the fourth alone sounds sharper. Consequently the leading note is less insistent, melodically, on being followed by the tonic since the semitone is so wide. This does not impair the harmonic feeling of the dominant chord being followed by the tonic chord, in fact, if anything, the result is more satisfactory, since both chords sound more in tune than do equally tempered chords.

The foregoing description is only of quarter comma meantone, the most usual of the meantone temperaments. Other forms of it have been described and considered to be as regular, some even being preferred to it.

Zarlino in Institutioni Armeniche (Venice 1558), described "a temperament in which each fifth remains diminished and imperfect by 2/7 comma". This system, Zarlino himself admitted, is not so good as quarter comma. He also described a system having nineteen notes to the octave to be applied to a cembale which Domenico Pesarese had made for him.

Salinas (1513 - 1590) outlines "three ways of tempering imperfect instruments" in his De Musica libri Septem, published in 1577.

The first is to divide the comma into three proportional parts, giving one to the minor tone and taking two from the major tone. This gives a new tone larger than the minor and smaller than the major. The decrement is twice the increment and through the maximum inequality the tone becomes equal.

The second divides the comma into seven proportional parts, giving three to the minor and taking four from the major tone.

The third will arise from halving the comma giving half to the minor and taking half from the major tone.

The second of these temperaments he attributes to Zarlino (2/7th. comma?) and the third (quarter comma) he says was commenced, but not perfected by Ludovico Fellicano of Moderna. "The first," he writes, "so far as I know, has been laid down by no one." This is 1/3 comma meantone and is again inferior to quarter comma except in an octave of nineteen notes.

It is also interesting to note that Salinas adds, "Wherefore any one of these temperaments seems most suitable for artificial instruments, nor have any more as yet been thought out." This seems to state quite clearly that Salinas did not consider equal temperament as a possibility in 1577 nor did Zarlino before him, since he seems to be acquainted with Zarlino's work.

Other varieties of meantone, described in detail by J. Murray Barbour (9) are, 1/5 comma (Verheijen, Rossi and 'Guidonian'), 2/9 comma (Rossi), 3/10 comma (Harrison), 5/18 comma (Smith), 1/6 comma (Silbermann), whilst 1/7, 1/8, 1/9 and 1/10 comma have also been described, 1/11 comma being equal temperament.

(9) Barbour, J.M. Tuning and Temperament. East Lansing. Mich. 1953. p.31 ff.

The Silbermann (1683 - 1753) temperament,  $1/6$  comma meantone, is worth noting even though Silbermann lived much later than the period under discussion. By spreading the syntonic comma over six fifths instead of four, the fifths are slightly better than those of quarter comma but the thirds are less good, being slightly sharp. Some of the 'wolves' could be removed to remote keys allowing more 'good' keys to be available, and it had the advantage over equal temperament that the thirds were nearer true. This was a half-way stage between meantone and equal temperament.

Meantone temperament persisted well into the nineteenth century although it was out of fashion as a temperament for pianes. In fact, it is not unreasonable to say that equal temperament is the pianeforte temperament. Only one organ in the Great Exhibition of 1851, an instrument made by Schulze, was tuned to equal temperament, the others were meantone tuned. The date of the first commercially produced organs, equally tempered, seems to be 1854 when Gray and Davison made their first organ to be built and originally tuned in equal temperament. In the same year both Walker and Willis sent out their first equally tempered organs. Equal temperament was officially introduced into the pianeforte trade in England a little earlier, in 1846, when Broadwoods first began to use it.

Although these are the official dates of introducing equal temperament by the firms concerned, the temperament itself was known and used in England much earlier than 1846. William Crotch (10) writing in 1812 said, "As organs are at present tuned keys which have many flats and sharps will not have a good effect especially if the time is slow," a reference to meantone or some temperament in which all keys were not equally in tune. Later in the same book he wrote, "Unequal temperament is that wherein some of the fifths, and consequently some of the thirds, are made more perfect than on equal temperament, which necessarily renders others less perfect. Of this there are many systems, which the student is now capable of examining for himself." Clearly there was a diversity of tuning in 1812, equal temperament being one of the possibilities. The "unequal temperament" mentioned does not seem to be quarter comma meantone, because all the thirds of that temperament would be better than equal temperament (except in the keys which are not available at all), but all the fifths would be worse. In any case, it

(10) Crotch, W. Elements of Musical Composition. London. 1812.



would appear that the thirds were not all equally good because it suggests that only "some of the thirds" are better than equal temperament. This sounds like one of the irregular temperaments, such as those suggested by Werckmeister, in which some of the fifths are flatter than in equal temperament, but all are less flat than those of quarter comma meantone. The thirds also vary, some being better than those of equal temperament, some worse, but none were true as in quarter comma meantone. The most important fact from the above quotation, however, is the diversity of temperament at the beginning of the nineteenth century.

Although the adoption of equal temperament as the standard tuning of keyboard instruments is comparatively recent, it has always been a possibility. Aristoxenus, a pupil of Aristotle, is said to have advocated it, at least, it is implicit in his statement that the fourth consisted of two tones and a half, because this is only true in equal temperament. Mersenne, in Harmonie Universelle (1635), gives the correct numbers for the ratios of equal temperament. Werckmeister, in Orgelprobe, (second edition, 1698), recommends equal temperament, and Schnitger, an admirer of Werckmeister, built the organ of St. Jacobi - Kirche in Hamburg in 1688 and tuned it in equal temperament. Frequent reference is made to equal temperament on organs in North Germany about the beginning of the nineteenth century, and Dr. Robert Smith must have had some experience of it to be able to write in his Harmonics (1759) of, "that inharmonious system of twelve hemitones," producing a "harmony extremely coarse and disagreeable."

J.S. Bach is often credited with the introduction of equal temperament, although this is not now supported (11). No doubt Kirnberger was correct when he asserted that when he was a pupil of the elder Bach he had been made to tune all major thirds too sharp, but this could be true of many temperaments as well as equal temperament.

In meantone temperament the syntonic comma is spread over a particular number of fifths, but the full cycle of fifths is not complete. Only in equal temperament is this completion accomplished and all keys made equally out of tune, although some forms of irregular temperament will make it possible to play in all keys.

(11) Barbour, J.M. Musical Quarterly. Jan. 1947.  
Article. 'Bach and the Art of Equal Temperament.'

Example 5.

In the above cycle of fifths, the top B sharp must coincide with C since there is no other possible note for it on a keyboard (as E sharp must coincide with F, A sharp with B flat and so on if all the possible keys are to be obtained). In true intonation, however, these notes are not the same. In the description of meantone temperament it was shown that F sharp is 0.9 of a syntonic comma flatter than G flat if both notes are perfectly in tune, all other enharmonic changes can similarly be shown to necessitate a change in pitch if they are to remain perfectly in tune.

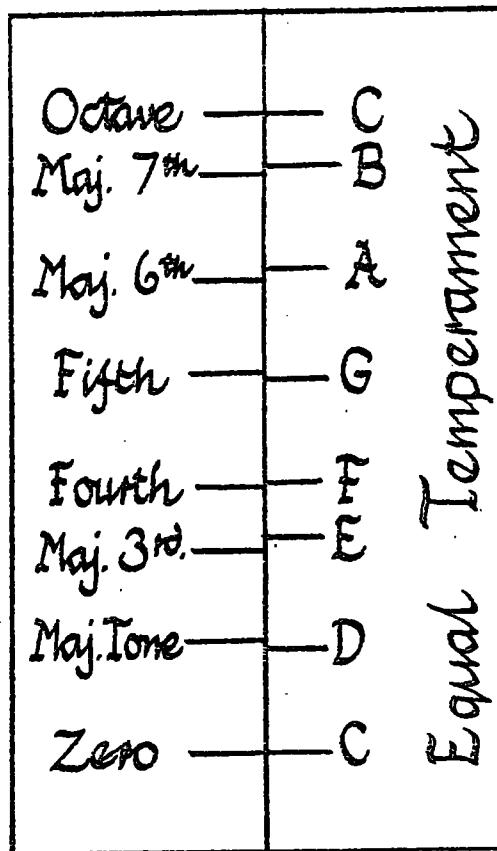
Equal temperament is the only compromise which will even out all these discrepancies, though other temperaments can make them tolerable. Since twelve fifths exceed seven octaves by the comma of Pythagoras, if each fifth is tuned  $\frac{1}{12}$  of such a comma flat then twelve fifths will equal seven octaves, F sharp will equal G flat, A sharp will equal B flat and so on.

Since the comma of Pythagoras is a small interval, the mistuning of the fifths is slight, in fact it is almost unnoticeable even on such a sharply defined interval as a fifth. The thirds present a greater problem. It has already been noted that a major third consists of a major tone and a minor tone (or two mean tones). A tone in equal temperament is not a major tone, a minor tone or a meantone. Of the three it is nearest in size to the major tone and it is easy to work out why this is so.

Again reference must be made to just intonation which presupposes a scale with mutable notes. If we again choose the scale of C major, the mutable note will be D. Tuning up from C an equal tempered fifth to G and then down an equal tempered fourth (which will be slightly sharp since the fifth is flattened) to D will produce a tone C to D

which is slightly less than a major tone. Tuning up an equal tempered fifth from this D will produce an A considerably sharp of a true major sixth from C, because the true major sixth would be formed as a true fifth above D a minor tone above C. Tuning down an equal tempered fourth from this A will produce an E which is considerably sharp of a true major third. Tuning up an equal tempered fifth from this E will produce a B which is sharper than a true major seventh above C. The scale which results is shown, drawn against a true scale as Fig. 2., and against a meantone scale as Fig. 3., both these diagrams are taken from Intervals, Scales and Temperaments, pages 67 and 104 respectively.

Equal temperament gives a keyboard player or composer more scope to move away from the original harmonic centre of the music without the 'wolves', but in return for the silencing of the 'wolves'



..... Fig. 2.

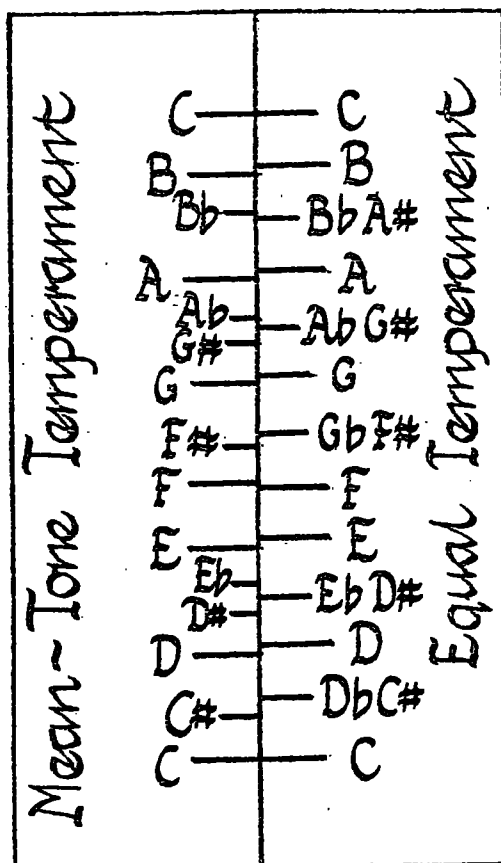


Fig. 3. ....

he must pay by having harmony, which, by standards of perfect intonation, is rough. As late as 1879, William Fole is complaining about the effects of equal temperament in The Philosophy of Music.

The modern practice of tuning all organs to equal temperament has been a fearful detriment to their quality of tone. Under the old tuning an organ made harmonious and attractive music, which was a pleasure to listen to ..... Now, the harsh thirds, applied to the whole instrument indiscriminately, give it a cacophonous and repulsive effect.

Most of the temperaments described have been regular, that is, they have contained adjustments from true intervals which are consistent throughout. The only temperament so far mentioned which is not of this type is that of Werckmeister. The following layout for one of his temperaments shows the cycle of fifths as complete, with the 'fifth' D sharp to B flat as the turning point between sharps and flats. It is obviously intended that all keys should be usable and the following passage, given as a footnote by Arnold (12), shows how this was to be worked out:

(12) Arnold, F.T. Art of Accompaniment from a Thorough Bass. London. 1931. Reprinted London 1961.

The temperament which he advocates, as explained in an appendix: Kurzer Unterricht und Zugabe, wie man ein Clavier stimmen und Wohl temperiren Kønne ('Short Instructions and Supplement, as to how a clavier may be tuned and tempered'), is a form of unequal temperament in which all the major thirds are slightly sharp (especially G sharp and D sharp), while most of the fifths are slightly flat. The exceptions are best described in Werckmeister's own words: "with this C sharp the fifth, G sharp, can be tuned almost true (i.e. infinitesimally flat); the test for the G sharp is E, this third is usually a little too much on the sharp side (diese Tertia pfleget wohl ein wenig scharf zu fallen), but if one contemplates using the G sharp in place of the A flat, as F A flat C, it cannot be helped. With the G sharp the fifth D sharp is tuned. The D sharp may be just a little sharp in relation to the G sharp, in order that it may be tolerably consonant as a major third to B and as a major third to G (i.e. when used as E flat). With this D sharp the octave D sharp is again tuned true; with the D sharp the fifth B flat may be tuned, which may also be slightly sharp, in order that the D may be tolerable as its appropriate third.

"With the B flat the fifth F may be tuned, again slightly sharp, or quite true, according to how the F sounds in relation to the E, as the last Terminus \*, or, again to the last test note A, as the major third F to A \*\*."

\* A 'leading note' (in the wider sense of the term) was called Terminus Acutus or Terminus Gravis, according as the resolution was upwards or downwards. Thus the upper notes of an augmented sixth or fourth and the lower note of a diminished fifth are termini acti, while the opposite extremes are termini graves.

\*\* The major thirds are to be used throughout as tests: if their sharpness is excessive the fifths must be flattened.

Werckmeister's whole scheme (given in accordance with his own minute instructions) is as follows: the round black notes represent the standard notes, and the white notes those which are tuned with them, while the diagonal line notes are the tests:

Example 6.

The image shows three staves of musical notation. The first staff contains notes with various accidentals: a natural sign, a sharp sign, a flat sign, a double sharp sign, a double flat sign, and a sharp sign with a flat sign. The second staff contains notes with sharp signs and accidentals. The third staff contains notes with flat signs and accidentals.

The Werckmeister temperament did not appear in print until the end of the seventeenth century, but it seems likely that the idea of using an irregular type of temperament was not entirely new. It is possible that such temperaments were the culmination of a process of evolution rather than an idea arrived at in its entirety without any precedents, but whether such precedents did exist so far ahead of Werckmeister as to influence the music under discussion in this study is a matter of conjecture.

Possible alterations to meantone, made available by choosing notes other than these in the standard temperament and extensions of it by the use of split keys seem more likely ways of enlarging the number of available chords than the use of irregular temperaments. An E flat could easily be replaced by a D sharp if the third from which the note was set was below instead of above it (i.e. the note was tuned as a true third above B instead of a true third below G). Similarly, A flat could be tuned as a true third below C instead of G sharp which would be a true third above E. All the chromatic notes can easily be altered in this way without needing to reset the complete scale.

If an instrument had split keys (other than those required for the broken octave bass), the standard meantone temperament could be used and some of the alternatives suggested above added to it. There were seldom more than three additional keys (making fifteen notes to an octave) added to instruments, with the exception of the Archicembalo (thirty-one notes to the octave) and the Clavicembalum Universale (nineteen notes to the octave). The three notes usually added were D sharp, A flat and A sharp.

Since, according to Peter Yates, "the use of tempered Pythagorean for the English Elizabethan music seems very probable," a statement of his on the laying of such a temperament needs to be included. I quote from Peter Yates:

The first tempered scales were certainly a modified Pythagorean. Leaving the perfect fifths C - G, G - D, A - E, E - B (as tuned for Pythagorean), the tempered fifths might have been B - F sharp, F sharp - C sharp, C sharp - G sharp, F down to B flat, B flat down to E flat. C down to F may have been tempered or left perfect. The enharmonic intervals E flat - D sharp, A flat - G sharp, B flat - A sharp, G flat - F sharp, may have been adjusted according to the harmonies desired. Other adjusted variants of the tempered Pythagorean tuning would have been tried. For the listener the general effect of such a tuning

would still be that of perfect fifths. (13)

This temperament gives sharp thirds, particularly those in the chords of C major and G major and the general feeling that the temperament contains perfect fifths is only gained at some cost to the thirds. A fuller description of the musical effect will appear later when the music is considered in more detail; it is sufficient here simply to describe the temperament.

Although temperaments can be worked out and described, they must be correctly set by someone. To be correctly set they must be correctly heard. To facilitate tuning quarter comma meantone, A.J. Ellis, the translator of Helmholtz, suggests the following means of setting a scale by counting beats:

Tune in the following order, the numbers 25-6-7 and 40-41-42 meaning that the beats are to be 25 and 40 for low, 26 and 41 for medium and 27 and 42 for high pitch in 10 seconds according to the three grades already laid down.

c 25-6-7, g 40-41-42, d 25-6-7. a 40-41-42. e 25-6-7,  
b 40-41-42, f sharp 40-41-42. c sharp 25-6-7. g sharp 40-41-42,  
c 40-41-42, f 40-41-42, b flat 25-6-7. e flat 40-41-42, a flat.

(the three grades of pitch referred to are:

Low	-	Handel's pitch	c. 252.7	
Medium	-	Helmholtz's pitch	c. 254	
High	-	Durham Cathedral Organ	c. 283.6	
		Father Smith's pitch.	)	(14)

In the end, it is just as difficult to count beats as it is to assess the amount of flatness or sharpness of the intervals by judgment and experience. Theoretical possibility and practical possibility must go hand in hand, because it is how the temperament sounds which matters most from a musical point of view rather than how cleverly it seems to spread the effect of the discrepancies in the use together of true octaves, fifths and thirds. How well the actual tuning corresponded with the theoretically accurate figures for the temperament is now impossible to say. Something so ephemeral as a tuning and something so inexact in practice (because most tuners admit it is more difficult to 'chase the wolf away' on some days and on some instruments than it is on others), can never be positively recreated, but it is only in attempting such recreations and in trying to find out the amount of dissonance which would have been tolerated that we can come closer to the practice of the day.

(13) Yates, P. An Amateur at the Keyboard. London. 1965.

(14) Helmholtz, H. On the Sensations of Tone.  
Trans. 1885 by A.J. Ellis. Appendix xx.

## CHAPTER 5.

THE EVIDENCE OF THE MUSIC.

"It is not to be expected that a study of the music will provide a precise picture of tuning practice." (1)

The above quotation is taken from a chapter headed "From Theory to Practice" and it is easy to see Dr. Murray Barbour's point of view. When a chord of C major is written down, there is no indication on the music to say how the chord is to be tuned. If it is for a group of instruments with flexible pitch, one could assume that the chord should be fairly free from beats, but on a keyboard, it can only mean that chord formed by the depression of the notes C, E and G on the instrument as you find it, unless you are in the fortunate position of being able to tune the instrument yourself.

One course of action will be to see what has been written at or near the time of the composition of the music by its composers, and by musical theorists. We may still be little better off. Unless some direct connection between the writings and a particular group of musicians or tuners can be firmly established, it is still an open question as to which temperament was used. We will, however, be narrowing the field of investigation, because the omission of mention of a particular temperament, modified Pythagorean temperament, for instance, or a reference to general usage, such as the adoption of equal temperament by British organ builders in 1854, will give us useful clues about the direction to follow.

The instruments themselves may be helpful, but there can be no guarantee of this. If the instrument has only twelve notes to the octave, those notes could have been tuned in many different ways. If it has more than twelve notes to the octave we may be looking at an instrument which was not in general use. This is not necessarily such a great difficulty as it would be today. Music would not be so generally available as it now is and could well have been confined to the areas in which the instruments would be, namely, among those people or institutions that could afford them.

Some instruments do tell a more positive story. The Ruckers transposing harpsichord described in the chapter on instruments must suggest meantone tuning. It also suggests that it must be a type of meantone which has an E flat and a G sharp (or possibly a D sharp and an A flat?), and the most likely type would be quarter comma meantone. Split keys

(1) Barbour, J. Murray. Tuning and Temperament. A Historical Survey. East Lansing. 1951. p.185.



for E flat/D sharp, G sharp/A flat and B flat/A sharp must suggest a temperament in which these notes are not identical, and they are normally considered to be extensions of meantone.

Another source of information is the oral tradition of instrumental tuners or any written records of long established firms. Present day tuners know only equal temperament, but a firm like Broadwood, which can trace its history back to the eighteenth century, gives an approximate date of 1846 for the adoption of equal temperament as standard temperament for their pianos. Most crafts hand on practical information irrespective of pronouncements by theorists, or perhaps incorporate the practical implications of such pronouncements into their 'lore' when the point has been proved in practice. Professional associations are generally somewhat conservative in this way. Conversely, however, some things are discovered by practising craftsmen long before they can be, or are, explained in theory. With such an ephemeral thing as a temperament on a keyboard instrument it is difficult to be sure whether the theorist is describing common practice or the craftsman is confirming the ideas of the theorist.

From these considerations it appears that the only definite lead suggests meantone tuning. In England, at least, equal temperament was not officially recognised as standard until well into the nineteenth century, although it seems impossible to imagine much of the music which was being written even about seventy-five years or more before that time being played on meantone tempered keyboards. Whether the tunings used were quarter comma or not is again uncertain, but if one judges from the complaints about the harsh thirds produced by equal temperament, the thirds which preceded its introduction must have been reasonably good and so would suggest quarter comma tuning.

Ultimately the only tangible evidence is the music (even though we are in the hands of copyists), and whether we can see it clearly or not, the truth can only lie there. Study of theoretical writings and instruments is necessary, but the answer must lie somewhere in the music if we are to interpret the meaning of what we see and hear. Hearing with ears accustomed only to equal temperament is rather like assessing buildings having only viewed the concrete boxes with which we are now forced to live. Any judgment on Elizabethan architecture having such structures as a norm must be suspect; so must judgments made on temperament without recourse to actual knowledge of temperaments other than equal temperament.

Discussion of this subject began because of the many conflicting views expressed about temperaments. The phrases, "some approach to equal temperament" or "some form of equal temperament" seem to suggest that equal temperament was unlikely from an historical point of view but seemed inevitable from a practical point of view. Historically, meantone should be the correct temperament, and in the ensuing discussion, the existence of meantone tuning will be assumed for the sake of argument.

Taking this as a starting point, the differences between meantone and equal temperament might give us a means of looking at the music afresh, since just intonation is denied us on a keyboard. The main differences between meantone and equal temperament are:

- (1) the tones of meantone are smaller steps than those of equal temperament.
- (2) the meantone diatonic semitones are larger steps than those of equal temperament.
- (3) the diatonic and chromatic semitones of meantone are different in size; in equal temperament they are equal in size.
- (4) the major thirds of meantone are narrower than those of equal temperament.
- (5) the minor thirds of meantone are wider than those of equal temperament, but the enlargement of the meantone minor third does not equal the flattening of the meantone major third because .....
- (6) the fifths of meantone are flatter than those of equal temperament.

As far as sound is concerned, these differences mean:

- (a) chords with roots a tone apart do not sound so far removed from each other in meantone as they do in equal temperament.
- (b) chromatic semitonal changes are not so abrupt in meantone as in equal temperament because the distance between the notes is smaller.
- (c) augmented and diminished intervals are different in sound on a meantone temperament. On an equally tempered instrument an augmented second equals a minor third and a diminished seventh equals a major sixth; this is not the case on a meantone tempered instrument.
- (d) chords with roots a major third apart do not sound so remote from each other tuned meantone as they do equally tempered.....whilst.....

(e) chords with roots a minor third apart are a little more distant from each other in meantone than in equal temperament.

(f) temperament is an harmonic rather than a melodic necessity, but since the temperament alters the scale, it does alter the melodic effect of the music, so this too must not be forgotten.

Alongside the considerations of temperament must be taken some of the characteristics of style. The most obvious is the frequent use of false relations. When notes in false relation to each other are used in different voices in close enough proximity to each other to be noticeable, we can use the term false relation, but everything must hinge on the definition of close enough proximity. I have tried to be more specific than that, and have only called the following occurrences false relations:

- (1) the two notes in question are struck together.
- (2) a note is struck against a held note in false relation to it.
- (3) the two notes in question appear in different voices in adjoining chords.

Added to this must be the so called English, or false relation, cadence, but in this case close proximity needs to be accepted as well as the three situations mentioned above. Since this is a recognised cadence, the definition of proximity need not trouble us.

Another characteristic of style involving the chromatic alteration of a note is the frequent change from major to minor (or vice versa). This is different from false relation in that the note in question usually stays in the same part and it is likely to occur in a block chordal context. This latter contingency is only a likelihood, not a certainty, and change between major and minor versions of the same chord appear in running passages too.

The most frequent of the characteristics is the change between major and minor chords, but false relations run it a close second. Almost all the composers studied use the devices, some much more frequently than others.

There are more instances of the use of false relations in Byrd's works than in those of the other composers. Of the 122 compositions which appear in his collected works for keyboard (Musica Britannica

Vols. xxvii and xxviii), sixty-one contain false relations. The Galliard (M.B. xxviii No.52b), for instance, has one false relation at bar twelve:

Example 7.



but it also contains some near misses, such as

Example 8.



and the following change of chord, which is quite a jolt in equal temperament, though not so much so in meantone:

Example 9.



The logic of the harmony is quite clear. Bars 32 and 33 have a similar progression to bars 4 and 5.

Example 10.



the F, harmonised as a third above D in bar 5, is harmonised as the root of the chord of F in bar 33.

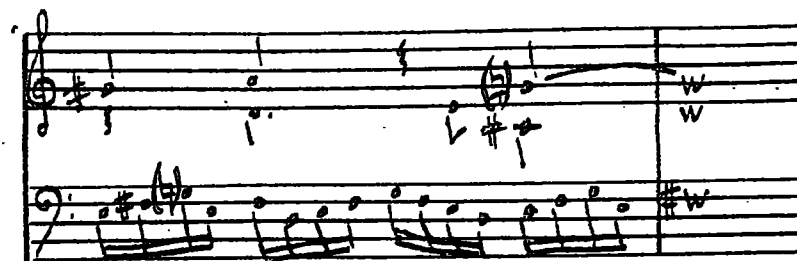
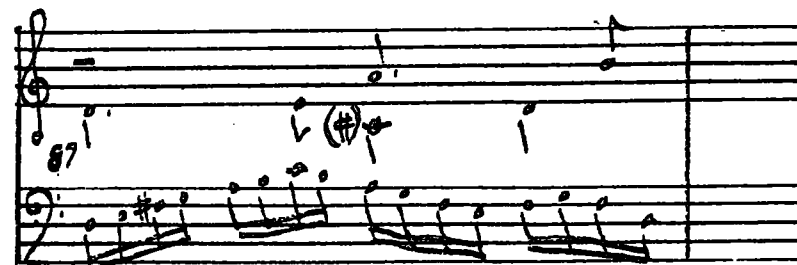
Some pieces contain many instances of false relation. The Quadran Paven (M.B. xxviii No. 70a) has some fifteen instances, very often in the form of an English cadence with the false relation struck:

Example 11.



or, as in the following example, a note is struck against a held note in false relation to it:

Example 12.



When our knowledge of the sound of harpsichords was gained from reading books rather than listening to instruments being played, we might have been led to believe that the harpsichord's alleged lack of sustaining power would minimise the effect of this type of false relation. The opposite is nearer the truth. The harpsichord has considerable sustaining power; add to this its more incisive sound which will make inner parts clear and sharp, and a passage like the one quoted at Ex. 12 becomes a prominent feature, having almost a sour edge to it.

A final quotation from the Quadran Pavan shows the alteration of notes in different parts in close proximity to each other, not, in this case, in adjoining chords, but with only a chord or two in between:

Example 13.

The appearances of false relations are frequent in the works of other composers too. The following list gives some indication of the frequency of occurrence in the works of some of the major composers.

W. Byrd	122 pieces checked	61 with false relations
J. Bull	165 pieces checked	46 with false relations
O. Gibbons	50 pieces checked	7 with false relations
T. Tomkins	73 pieces checked	25 with false relations
G. Farnaby	53 pieces checked	18 with false relations

Of false relations Hilda Andrews writes:

The sung effects of "false relations" is, of course, softer than is possible on a keyed instrument like the virginal, which must have been tuned on some system of equal temperament. (2)

Leaving aside the question of temperament for the moment, I will try to examine the softening of false relations when sung as compared with their being played on a keyboard instrument. Since Byrd uses them more than other composers and the quotation referred to appears in an edition of My Ladye Nevells Booke it seems appropriate to discuss an example from this book:

Example 14.



If the above example from My Ladye Nevells Booke piece No. 7 A Galliard Gigge (M.B. xxvii No. 18) were to be sung, or played on instruments with flexible pitch, the G sharp in the uppermost part would probably be kept as close as possible to the A, whilst the G natural in the lowest part would probably be close to the F sharp. This would "stretch" the interval G natural - G sharp as far as was tolerable, but at the same time keep the E major chord reasonably good. The fine "placing" of the G sharp in relation to its function as the third of the chord of E major and the leading note to A, could be accomplished with the minimum detriment to either function. In other words, this note would be tempered to suit the circumstances. The G natural has only melodic significance in its own line, so "placing" it close to the F sharp will help bind the melodic movement tighter as well as helping to avoid the harsher beating which would result from making the notes just. The result would be more like a true diatonic semitone than a true chromatic one.

(2) Andrews, Hilda. Historical Note to My Ladye Nevells Booke. New York. 1926. page xxix.

If the passage were played on an equally tempered instrument, the G sharp would be nearer to the A than would a just G sharp so it would make it close to the tempered G sharp spoken of in the last paragraph. But the freedom to "place" it precisely in the best position for both its functions would be lost. The G natural would be closer to the F sharp than a just G would be, so this note may again approach the position of the well placed G natural mentioned earlier, but since the equal tempered F sharp would be sharper than just, this would have the effect of narrowing the overall interval slightly. The G natural - G sharp interval must be wider than just in equal temperament since the major third is sharp and the minor third flat. The G natural - G sharp interval would, therefore, be "stretched" by the temperament, but not so accurately as it would be, with the flexibility of voices or violins.

Meantone temperament would come off worst so far as softening the effect of the false relation is concerned. The G sharp would form a just major third with E, whilst the G natural would make a slightly flat minor third. The meantone major third, being just, is less than the equal tempered third, whilst the meantone minor third is slightly larger than the equally tempered minor third. The resultant G natural - G sharp interval would be "stretched" just a little from true, but not so much as in the two cases described above.

But this is not the complete picture when discussing the bar in question. So far, only the distance between the G natural and the G sharp has been considered, that is, the "special effect" of the bar rather than its basis. The basic harmony is E major. In circumstances of flexible intonation, this chord could be held very nearly true, just erring slightly because of the pull of the chord of A major in the next bar. In meantone temperament the chord of E major would be fairly true, in equal temperament it would suffer from the sharp third.

To sum up, flexible intonation would be most finely controlled, would keep the basic harmony as pure as need be whilst allowing for the effect of the G sharp leading note, the melodic effect of the flowing bass line and the artistic handling of the discord. Meantone would keep the basic harmony correct, would make the G sharp sound rather flat as a leading note and would "stretch" the discord slightly. Equal temperament would give the purest basic harmony, a reasonable leading note and would "stretch" the discord. Flexible intonation,



which would imply different parts for each note, would have the added advantage that the G natural could be played or sung with less force (possible on a piano but not on a harpsichord), which would soften the effect of the discord even more. Of the two fixed temperaments, meantone would do least violence to the bar as a whole and would produce the greatest "effect" from the discord.

The close juxtaposing of major and minor chords is a feature which occurs too frequently to make counting the instances worthwhile. It is not unique to keyboard music, but examples of it can be found in almost every one of the keyboard pieces I have studied. John Bull's In Nomine (M.B. xiv. No.28) makes use of it on numerous occasions, the following examples being a selection:

Example 15.



Example 16.



Example 17.

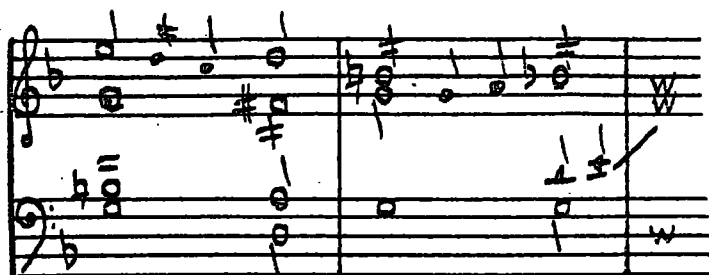
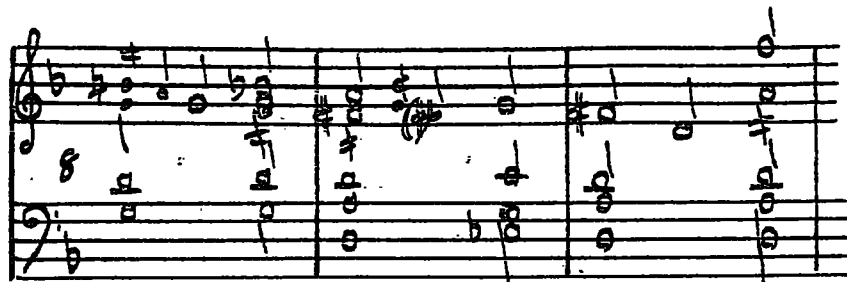
Many are less spectacular, like this extract from a Fantasia by Giles Farnaby (M.B. xxiv No.5):

Example 18.

whilst some are slightly ambiguous, such as the following bar which is taken from the same piece. The chords on beats one and two are A major, but that on beat three could be A minor or C major:

Example 19.

Quite often the major and minor chords appear side by side as in this quotation from Byrd (M.B. xxvii No.9):

Example 20.

and this from Merley (F.V.B. No.12):

Example 21.

The distance between a major third and a minor third is a chromatic semitone. Equal temperament makes each semitone equal so diatonic and chromatic semitones are the same. Meantone temperament makes the diatonic semitone wide (since the third is tuned true and the fourth is slightly sharp). The meantone chromatic semitone is also a little wider than just, because the major third is true and the minor third is slightly narrow. The equal tempered major third is wide and the minor third narrow, narrower than a meantone minor third. The equal tempered chromatic semitone is therefore a much wider interval than either a meantone or a true chromatic semitone. This must be the case if the same semitone is also to be serviceable as a diatonic semitone. Even so the equal tempered diatonic semitone is still narrower than a true diatonic semitone.

The basic differences between true, meantone and equal tempered chromatic semitones given above show the difference between a major and a minor chord on the same bass note is least if the chords are true and greatest if the chords are equally tempered. In this instance meantone is very near to true and this accounts for the fact that major - minor changes sound less distant from each other, or, rather, have more of a family likeness than when they are equally tempered chords.

Meantone diatonic semitones are wide, but mean tones are narrow. A mean tone is half way between a major tone and a minor tone, and an equal tempered tone is larger than a meantone though less than a major tone. These facts are described in some detail in the chapter on temperaments, and figs. 1, 2 and 3 show the differences in graphic form.

Chord progressions a whole tone apart are quite frequent in Elizabethan keyboard music. Particularly noticeable is the chord of the flattened seventh. The following is extracted from Resseter's Galliard set by Farnaby (M.B. xxiv No.21):

Example 22.

The image shows two systems of handwritten musical notation. Each system consists of a treble clef staff and a bass clef staff. The first system has a treble staff with a key signature of one flat (B-flat) and a bass staff with a '13' marking. The second system has a treble staff with a key signature of one flat and a bass staff with a '1' marking. Both systems end with a double bar line and a 'W' marking.

Other good examples occur in Byrd's John Come Kiss Me Now (M.B. xxviii No.81):

Example 23.

and The Woods so Wild (M.B. xxviii No.85):

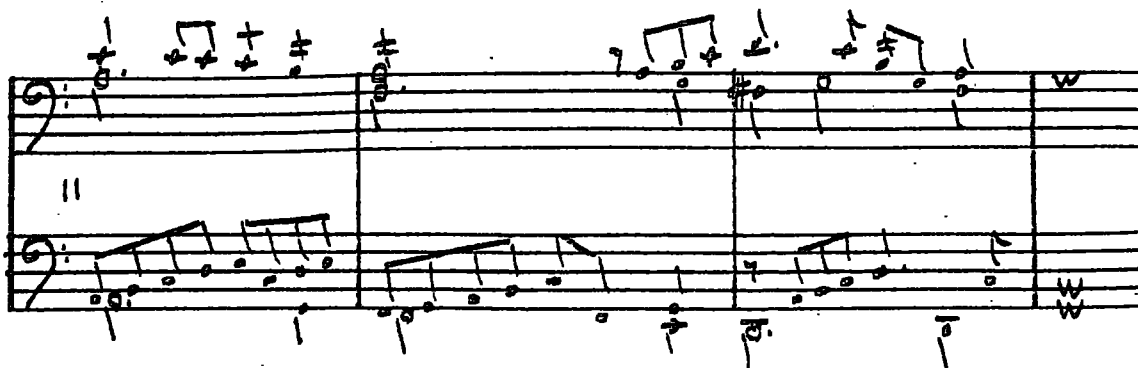
Example 24.

The following example of chord progressions a tone apart is taken from Why Ask You? by Bull (M.B. xix No.64):

Example 25.

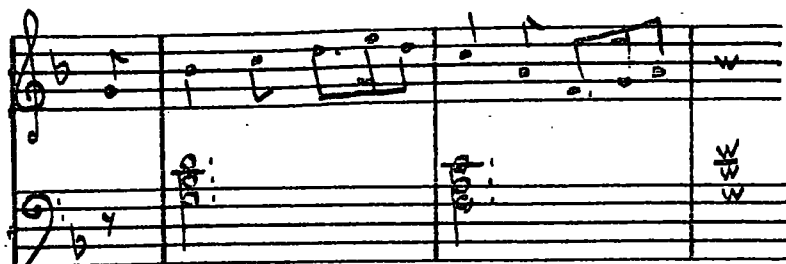
whilst a progression which extends even further using chords with roots a tone apart appears in The Italian Ground by O. Gibbens (M.B. xx No.27):

Example 26.



Examples of similar progressions could be taken from the works of all the other composers studied; the extracts given above are not exceptional cases. One must be on one's guard about what is being observed here. Chords a tone apart are the stock in trade of the modern "pop" and "folk" guitarists. They are easy to play on a fretted instrument since it is only necessary to move all fingers up or down two frets; there is no need to alter the relative positions of fingers. What is true of fretted instruments now is equally true of lutes then, and the keyboard derived some of its early literature from lute music. Allied to this is the observation that three of the four examples quoted are arrangements of popular melodies, and a glance at the opening of Greensleeves will show that the same progression is prominent.

Example 27.



In these cases we are probably looking at the natural use of the chord on the 7th degree of transposed Dorian mode (almost certainly so in the case of Ex. 27), rather than a deliberate attempt to use chords which sounded well on a meantone tempered instrument. The fact remains, however, that they are there, and they sound better closer together on

a meantone temperament than they do wider apart in equal temperament.

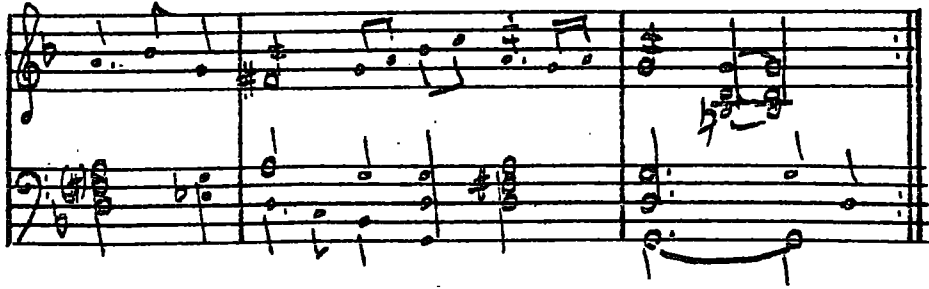
The reasons for this are not far to seek. Meantone is here again a closer approximation to true intonation than is equal temperament. Taking the two chords required to harmonise the first two bars of Greenleeves we find all the notes of the soft hexachord. The top note of the hexachord, D, will, in true intonation, be an exact major sixth above the lowest note, F. If this D were a true fifth of the chord beginning on G, the G would need to be a minor tone above F. A meantone is a closer approximation to a minor tone than is an equally tempered whole tone.

Further to this, the differences in the thirds of the two chords are worthy of note. The B flat of the G minor chord is a diatonic semitone above the A of the F major chord. This makes the major - minor change between the different chords more noticeable in meantone (as it would be also in true intonation) than it would be in equal temperament, just as the chromatic semitone change between major and minor on the same bass note is less noticeable in meantone and true intonation than in equal temperament.

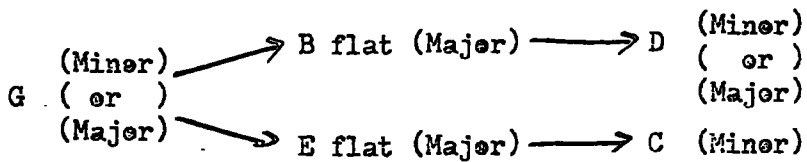
There is a strong tendency to use chords with roots a third apart. This has already been hinted at, but needs fuller investigation. The following example which forms the opening of Bull's Coranto "Alarm" (M.B. xix No.80) illustrates this clearly:

Example 28.

The image shows two systems of musical notation. Each system consists of a treble clef staff and a bass clef staff. The time signature is 6/4. The key signature has one flat (B-flat). The first system shows a sequence of chords and melodic lines. The second system continues the piece with similar harmonic and melodic structures. Some notes are marked with 'x' and '1', possibly indicating specific intonation or performance instructions.



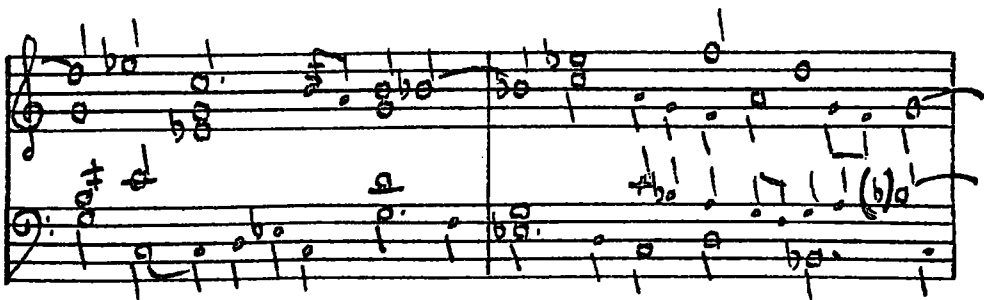
The current is written in the second tone, so the tonic chord would be G minor. The chords used in the passage radiate out from G in thirds thus:



Since this again is Dorian mode transposed, the chord on the seventh degree is available and we might expect to see it included somewhere, although this particular work does not feature it as prominently as many.

The Pavan (Lord Canterbury) of Tomkins (M.B. v No.57) begins thus:

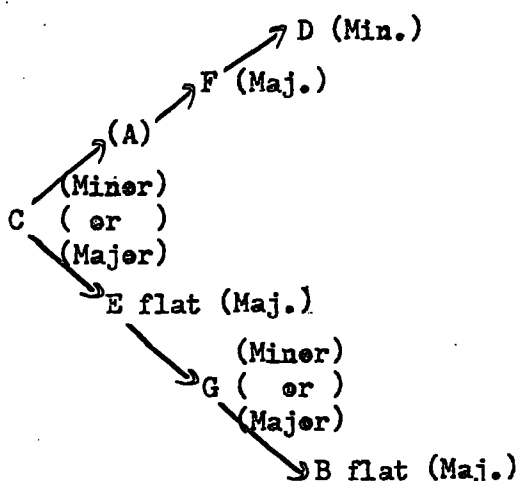
Example 29.







The chords this time radiate from a central C:



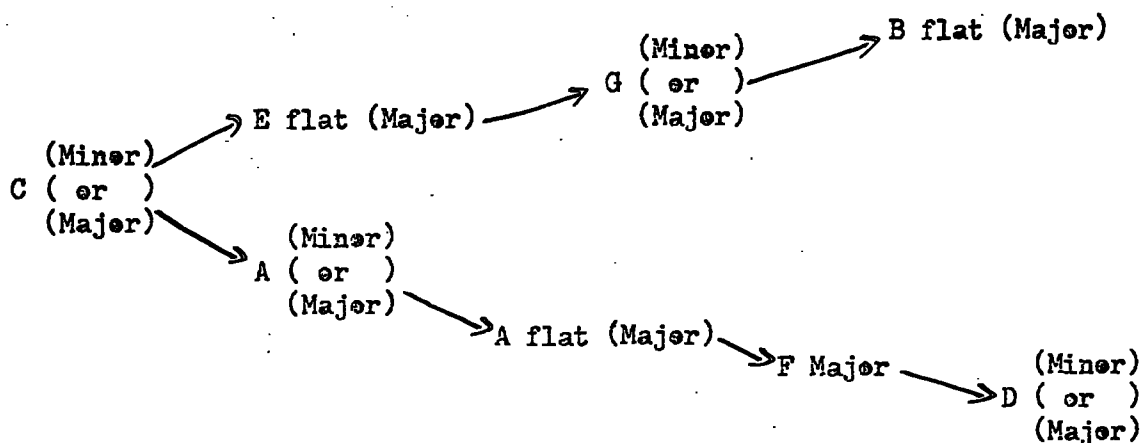
but the A is omitted up to this point. It is added in full measure later on, and not only is the gap between C and F closed, it is closed by two chords on A (i.e. Major and Minor) and one on A flat. It does not seem to matter whether the chords are minor or major, or whether the interval between the roots of the chords is a major or minor third. Example 29 forms bars 1-7 of the Tomkins Pavan; Example 30 is bars 19-23:

Example 30.





The pattern of chords now looks like this:

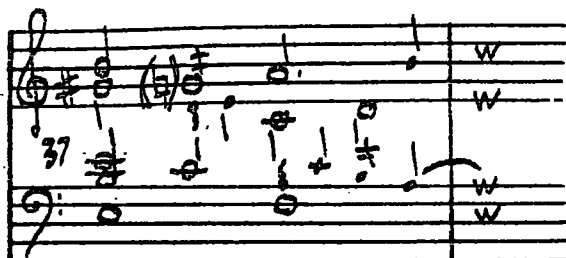


Apart from these examples of the extended use of chords with roots a major or minor third apart, the simple juxtaposing of major chords a major third apart is very common. The full harmonic significance of this merits further investigation but it is sufficient here to state that the movement between chords four sharps distant from each other was practised long before the Impressionist composers made use of it. As with the other characteristics, the use made by composers of this form of progression varies, but all composers made some prominent use of it somewhere. Of the five leading composers, the number of works in which it features is:

Byrd	122 pieces checked	29 had maj. chords a major 3rd apart.
Bull	165 " "	23 " " " " " "
Gibbons	50 " "	6 " " " " " "
Tomkins	73 " "	18 " " " " " "
G. Farnaby	53 " "	14 " " " " " "

Whilst this must be looked at as a harmonic device, the frequency of its appearance makes some statement about it and its effect in various temperaments worthy of inclusion.

Example 31. (MB xxvii No. 17)



In this example from Byrd, the placing of the chords E major and C major side by side causes a minimum of movement in just intonation. The tenor B moving to C would possibly be sharpened slightly and the alto G sharp would be a true chromatic semitone away from the G natural which follows. There would be little feeling that the chords were distant from each other. In meantone the effect would be slightly less smooth because the semitone B to C would be a large step. In equal temperament the case is very different. The G sharp would be very sharp and fall an equal tempered semitone to G natural, a larger interval than a chromatic semitone. The semitone B to C would be enhanced from meantone, but E falling to a C in the tenor would be a wide interval. The overall effect of two wide major thirds C - E and E to G sharp gives the characteristic remoteness between these chords which is not present when they are tuned true or meantone tuned.

Although the characteristics alluded to are of general interest in a study of temperament, of more particular interest is the number of notes used. If we are to accept Charles van den Berren's view that instruments were not tuned for "a particular piece written in a particular tenality ...." as meaning that no change of tuning would be made for playing pieces containing various notes, then we will be faced with a problem when discussing pieces which contain any note not in the standard meantone scale.

I think the case that no such alterations were made is far from proved, but at this stage I am still examining the facts, and the facts are that it is possible to alter one note on the instrument in a few seconds (e.g. D sharp for E flat, A flat for G sharp etc.) without needing to make any fundamental changes in the setting of the scale.

Of these pieces which require only one note altered from the standard meantone, by far the most common alteration required is D sharp

for E flat. This change is required in 57 pieces; in 49 of them it is the only alteration necessary in 5 it is required in conjunction with an A sharp and in 3 there are other considerations which render the piece difficult in meantone anyway.

I have tried to judge the relative importance of the note to be changed and have classified my results as follows:

**Essential** - when the harmony requiring the changed note is prolonged, or the note appears so many times that any fault in the intonation would not be tolerable.

**Highly desirable** - when the harmony is altered enough to be readily noticeable, even if the duration of the impaired harmony is short, or when the note concerned is in a somewhat exposed position.

**Desirable but tolerable** - when the note concerned is insignificant, forms an ornament or quick moving cadence figure, or could be ornamented in such a way as to make its presence almost unnoticeable.

In the case of substituting D sharp for E flat, in only 16 of the 57 pieces was the note absolutely essential and two of those, the Bull Hexachord Fantasia and the Tomkins Fancy; for viols, are not playable in meantone at all.

The following passages from Pavana Chromatica (Mrs. Kathleen Tregian's Pavan) by William Tisdall (F.V.B. No. 214) would be impossible without a D sharp:

Example 32. a.



Example 32. b.

The first quotation is the opening and the second is the final cadence. Another important cadence on B major occurs in the work and there are several other places in which the chord of B major is needed.

Veni Redemptor Gentium by John Bull (M.B. xiv No.42) contains the following bar in which B major harmony persists, but the other appearances of D sharp in the piece are insignificant:

Example 33.

This passage in a Pavan by Tomkins (M.B. v No.56) would also be intolerable without a D sharp, because the chromatic movement would be destroyed by the substitution of an E flat in addition to any harmonic dissonances which would be produced:

Example 34.

If the D sharp in the alto part of this bar from Morley's Pavan (F.V.B. No.153) were to be ornamented it could pass almost unnoticed if tuned as an E flat:

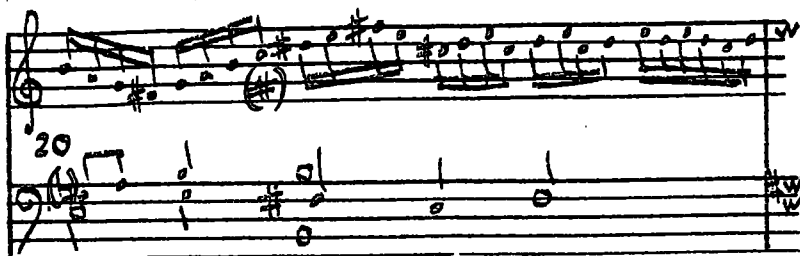
Example 35.



The bar has been copied as it appears in the Fuller Maitland - Barclay Squire edition of the Fitzwilliam Virginal Book, the sharp above the soprano D being editorial. If, as I suspect, this note was actually played as a D natural, forming a false relation, then D sharp would be preferable for the alto note rather than E flat. Even then, the D sharp would be preferable rather than essential.

There are 21 instances where the D sharp would be highly desirable but not so essential as in the instances quoted above. An elaborate cadence figure like this one from a Galliard by Tomkins (M.B. v No.46) would sound much better if the note in question was D sharp rather than E flat:

Example 36.



The speed of the passage helps to cover up the deficiency if an E flat is used, but seven D sharps in one bar all played as E flats could not pass unheard. A similar sort of elaborate cadence figure appears in What if a Day, again by Tomkins (M.B. v No.64); a D sharp is highly desirable.

In a Pavan by Bull the following ornamented D sharp appears (M.B. xix No.131.a.):

Example 37.

If the double line ornament is here interpreted as a trill and the ending is not turned, an E flat will do reasonably well. If a turned ending is used on the trill, the C sharp - E flat interval is too large to go undetected.

The Gibbens Fantasia (M.B. xx No.12) requires a D sharp on four separate occasions. Three of these are in cadence figures which could easily be ornamented (one, in fact, is so), to disguise an E flat, but the fourth is in a false relation cadence:

Example 38.

This D sharp could be a trilled E flat, but the false relation would then be impaired; a D sharp is preferable.

The harmony in this bar from a Giles Farnaby Fantasia (M.B. xxiv No.4) revolves around B major:

Example 39.

Although the first D sharp is short and the second, which forms the resolution of a suspended E, is ornamented, a D sharp is to be preferred rather than an E flat because of the harmonic importance of the chord of B major.

There are a further 20 instances of pieces containing a D sharp where an E flat could be used with little or no detriment. This quotation taken from a Galliard by Gibbens (M.B. xx No.24) is a good example:

Example 40.



The auxiliary notes, both of which have the sharp cancelled immediately, would not suffer by being E flats. They might even gain, since the E flat is closer to the E than a D sharp would be, and a string player faced with a similar situation would tend to play the D sharp very sharp.

When the only appearance of a D sharp in a particular piece is as follows:

Example 41.



it seems unnecessary to think in terms of altering the note from an E flat. This is more especially so in this Byrd Hexachord Fantasia (M.B. xxviii No.64) when the E flat is required for a large part of the piece. An instance such as this could hardly be used as a valid reason for saying the piece could not be played on a meantone temperament. As it happens, this particular Fantasia has other problems which render its



performance on a meantone tuned instrument difficult, but they will be discussed later.

There are 19 pieces which require an A flat for the standard G sharp of meantone. In 14 of these it is the only alteration, in the other five there are complications which will receive detailed individual attention at a later stage. Using the categories suggested earlier, in 9 of the pieces the A flat is essential, in 4 of them it is highly desirable, and in 6 a G sharp could be tolerated.

An A flat is only required twice in the Byrd Pavan (M.B. xxvii No.23.a), but on each occasion it is essential as the bass note of the chord and is half a bar in length:

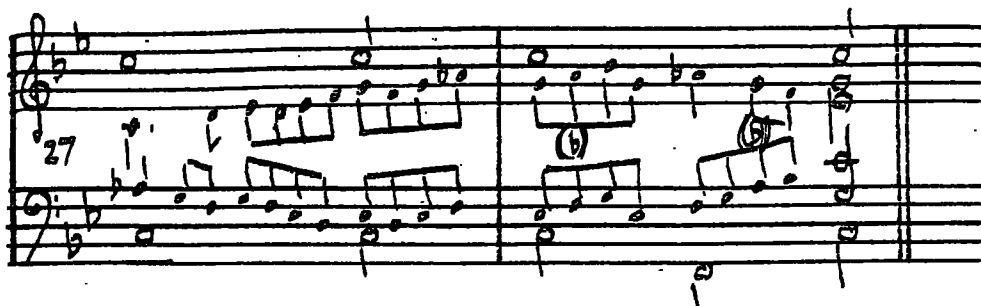
Example 42.

Again it is a necessity in the Derrick Prelude by Bull. (Cosyn) (M.B. xiv No.59). The Prelude is only seventeen bars long, but the chords of A flat major and F minor feature prominently:

Example 43. (note values halved).

In the example which follows, which comes from a Galliard by Thomas Warreock (F.V.B. No.98), the effect of the A flat is too long for it to be comfortably replaced by a G sharp:

Example 44.



Even if the A flats suggested by the editor were played as A naturals, it would still be an uncomfortable cadence because the "wolf" interval, G sharp - E flat, would be so much in evidence even though it is not actually struck.

An A flat may be highly desirable, but it is not essential in a passage such as this from a Galliard by Byrd (M.B. xvii No.31.b):

Example 45.

This is one of four pieces in which an A flat is highly desirable. Another is a Pavan by Thomas Warreock (F.V.B. No.97), which makes the first of a pair of pieces when coupled with the Warreock Galliard previously mentioned. It needs an A flat on six occasions, some of which are quite unimportant when the harmony is somewhat ambiguous

(Example 46.a), but others of which are more explicit (Example 46.b):

Example 46.a.

Example 46.b.

In six pieces the A flat is insignificant. The only time it makes an appearance in the Galliard by F. Richardson (F.V.B. No.29) is inessential from a harmonic point of view. A G sharp, being nearer to the G than is an A flat, might even enhance this auxiliary note although it would introduce the "wolf" fifth against the bass E flat.

Example 47.

The following bar taken from A Substantial Verse by Tomkins (M.B. v No.31) shows the only A flat in the piece to be even less significant than the previous example:

Example 48.

In neither of the last two examples would it be necessary to change the standard G sharp for an A flat. The speed and relative unimportance of the notes in question would render them unobjectionable even to the most sensitive ear although they might not pass undetected.

Three pieces require two alterations from a standard meantone scale; they are:

<u>Chromatic Pavan</u>	William Tisdall	F.V.B. No.214
<u>Fantasia</u>	Giles Farnaby	M.B. xxiv No.4
<u>Fantasia</u>	Giles Farnaby	M.B. xxiv No.9

Chromatic Pavan : William Tisdall : F.V.B. No.214

The two alternatives required are D sharp for E flat and A sharp for B flat. Some reference has already been made to the D sharp and some examples given (Examples 32.a. and b. on pages 71 and 72). It is sufficient to reinforce this by saying that in seventeen of the fifty-nine bars a D sharp is essential.

By contrast, the A sharp could easily be displaced by a B flat. The only appearances of the note are as follows:-

Example 49 a. and b.

The first appearance is already ornamented; the second is so like it that similar treatment would be reasonable.

Fantasia : Giles Farnaby : M.B. xxiv No.4.

The two alterations required are again D sharp for E flat and A sharp for B flat. The only bars concerned are quoted below:

Example 50 a. and b.



Bar 64 (Example 50 a.) has already been discussed, the D sharp being classed as highly desirable but not essential (Example 39, page 74).

The A sharp makes such a brief appearance that it could be faked by using an ornamented B flat. This is assisted by the cancellation of the A sharp in the alto part on beat four which alters the harmony from F sharp major (not available meantone) to F sharp minor (available meantone). The bar quoted as Example 50 b. is as it appears in M.B. xxiv No. 4. In the manuscript and in the Fuller Maitland - Barclay Squire edition of the Fitzwilliam Virginal Book, however, the F sharp bass second note is a G sharp. If the A sharp was in tune, the F sharp bass note would be better. If, on the other hand, it was an ornamented B flat, the G sharp of the manuscript would be better since it would minimise the feeling for F sharp major almost immediately.

Fantasia : Giles Farnaby : M.B. xxiv No. 9

This is an important work in the discussion of temperament. The three categories I have used for describing the desirability of a note over its enharmonic equivalent (since in meantone these do not coincide), must be viewed in the light of the written facts in this Fantasia. The discussion hinges round bars 18 and 19 which are quoted below:

Example 51.



Two alternatives from standard meantone seem to be required (D sharp and A sharp). The D sharp alteration I would class as highly desirable and the A sharp as quite passable as an ornamented B flat. The combination of both notes in such close proximity to each other would make me disposed to suggest that the D sharp was essential if the A sharp was replaced by a B flat. Two dissonances so close together I would not have found acceptable.

The same Fantasia appears in the Fitzwilliam Virginal Book as No. 208. In the Fuller Maitland - Barclay Squire edition these two bars are rendered:

Example 52.



Here, the chord of B major appears once with an E flat and once with a D sharp. The section is referred to in the Preface where the following representation of these bars appears, preceded by the given paragraph: (3)

The restoration of a note previously altered by an accidental, by means of a flat or sharp, contradicting a sharp or flat (of course the sign now in use for a natural is of far later origin), is of very rare occurrence; and in the great majority of cases this restoration has been made conjecturally ..... A curious example of the writer's inability to express a progression which was perfectly clear as far as sound is concerned, is to be found in the last bar of vol.ii p.270, and the first of p.271. These stand in the MS:

Example 53.



(3) Maitland, J.A. Fuller, and Squire, W. Barclay, The Fitzwilliam Virginal Book, London 1899. - extract from the Preface page xiv.

(A microfilm enlargement from the Fitzwilliam Museum and the editors note in M.B. xxiv confirm this.)

The importance of the quoted bars in the history of notation cannot be questioned. Their importance from the point of view of temperament can easily be overlooked if, on the keyboard we are using, D sharp equals E flat and A sharp equals B flat. On this score I cannot exactly agree that the progression is perfectly clear "as far as sound is concerned". In terms of sound, the progression, as it is written, is not clear; it only becomes so when the necessary enharmonic changes are made.

As it stands in the manuscript this Fantasia is playable on a standard meantone tuning. In bars 18 and 19 there would be a high level of dissonance since the notes required to complete the harmonic logic are not available. Perhaps we have in this brief passage an admission of the actual notes played, irrespective of the dissonance caused by them.

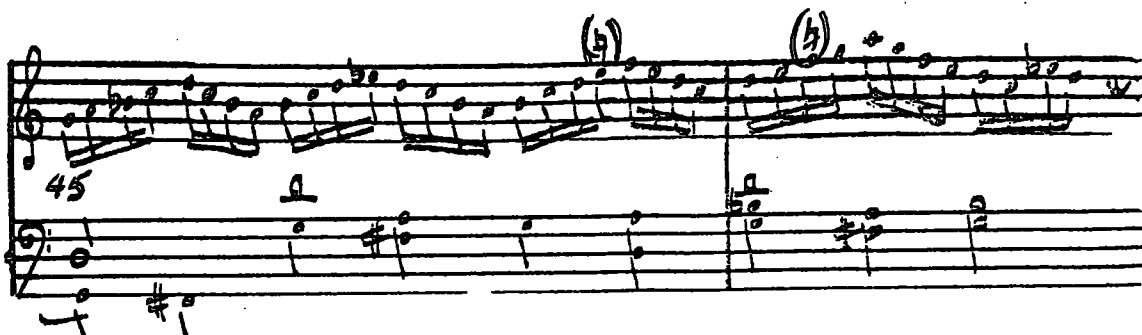
The final group of pieces to be studied are those which require an enharmonic equivalent as well as the standard note in a meantone tuning. For the sake of clarity later, I will refer to these pieces as requiring more than twelve notes to the octave. For instance, if both D sharp and E flat are required I will say that thirteen notes are needed in an octave, if D sharp, E flat, G sharp and A flat are required, then fourteen notes are needed to the octave, and so on.

Only twelve such pieces were found among those studied. They are:

Tomkins	<u>In Nemine.</u> Version 1	M.B. v. No.10
	<u>In Nemine.</u> Version 2	M.B. v. No.11
	<u>Voluntary</u>	M.B. v. No.30
	<u>A Substantial Verse</u>	M.B. v. No.31
	<u>Fancy; for viols</u>	M.B. v. No.33
	<u>The Perpetual Round</u>	M.B. v. No.66
G. Farnaby	<u>Fantasia</u>	M.B. xxiv. No.8
Byrd	<u>Hexachord Fantasia</u>	M.B. xxviii No.64
Gibbens	<u>Fantasia</u>	M.B. xx No.9
Bull	<u>Hexachord Fantasia</u>	M.B. xiv. No.17
	<u>Salvator Mundi</u>	M.B. xiv. No.38
	<u>Chromatic Galliard</u>	M.B. xix. No.87.b.

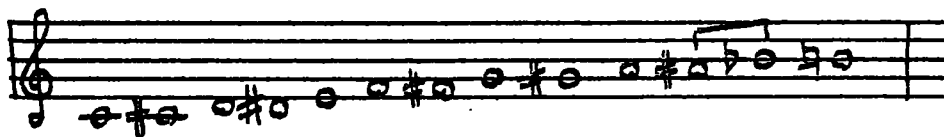
Thomas Tomkins : In Nemine. : M.B. v. Nos. 10 and 11.

The two versions of this In Nemine are better taken together because the same remarks apply to each. They require a thirteen-note scale, the additional note being D sharp. They present little or no problem in being played meantone, as the following extracts, which give the only appearances of the D sharps and E flats, show:

Example 54.a.Example 54.b.

Thomas Tomkins : Voluntary : M.B. v. No.30

The Scale required is:

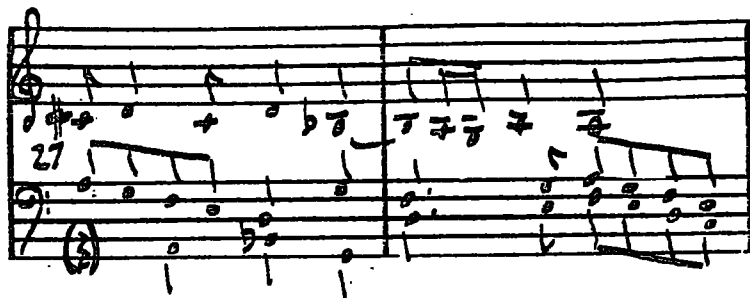
Example 55.

The additional note is an A sharp, but there is also a D sharp instead of the standard E flat. The A sharp makes only one appearance:

Example 56. (note values halved).

but the B flat is needed much more frequently:



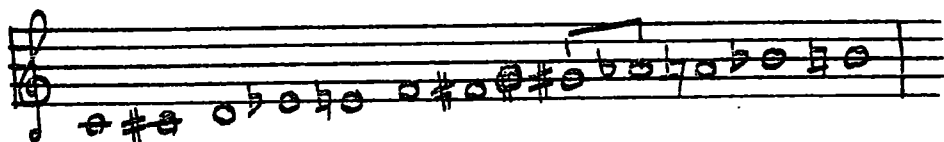
Example 57.

The D sharp appears three times at cadences, once in the soprano, and twice, like the instance quoted below, in the alto:

Example 58.

Thomas Tomkins. : A Substantial Verse. : M.B. v. No.31.

The scale required is:

Example 59.

The alteration from meantone is the addition of an A flat, whose only appearance is at bar 11 (see Example 48), and opinion about it has already been given.

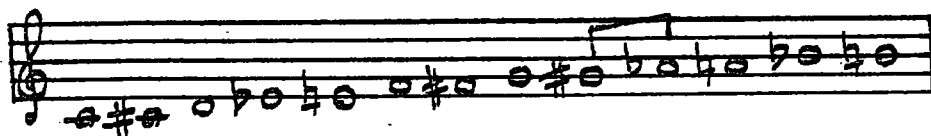
Thomas Tomkins. : The Perpetual Round. : M.B. v. No.66.

The Scale required is:



Giles Farnaby. : Fantasia. : M.B. xxiv No.8

The Scale required is:



The A flat appears in two bars:

Example 65 a. and b.

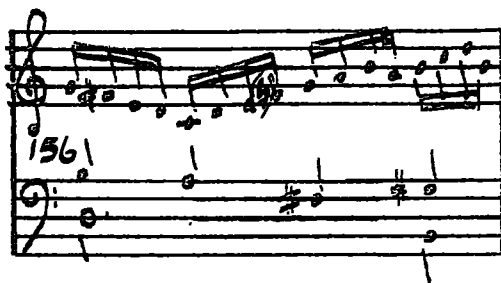


the G sharp in three:

Example 66 a. and b.



Example 66 c.

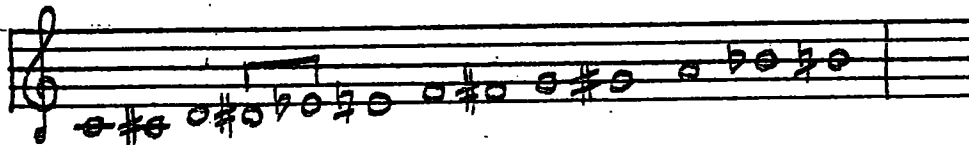


None of the appearances of each note are particularly prominent, nor would it do great violence to the music whichever of the notes in question was substituted for the other.

John Bull. : Salvator Mundi. : M.B. xiv. No. 38.

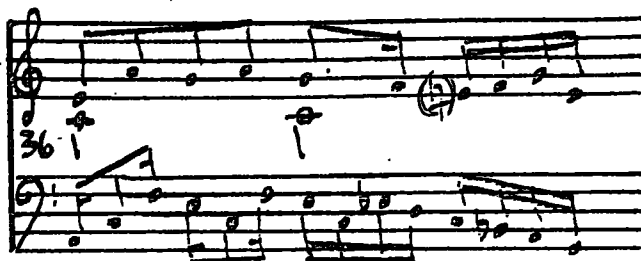
The Scale required is:

Example 67.



Both notes make only one brief appearance.

Example 68 a.



Example 68 b.

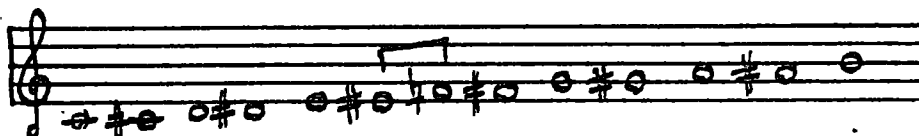


Since neither note has much significance it matters little which alternative is chosen, but the D sharp has a stronger claim to preference.

John Bull. : Chromatic Galliard. : M.B. xix. No. 87.b.

The Scale required is:

Example 69.



Again a scale of thirteen notes is required together with the alterations D sharp for E flat and A sharp for B flat from the standard meantone.

The absence of a D sharp would cause some discomfort in bars 43 and 44,

Example 70.



but its other appearances are of little significance.

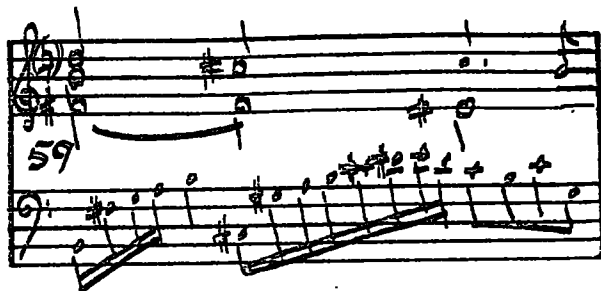
The A sharp is required in a similar cadence figure at bars 45 and 46, but in addition to this, bar 48 would suffer badly from a substituted B flat and bar 60 is identical to it:

Example 71.



The E sharp appears twice. Once in a typical cadence figure, Example 72.a., and the second time again at a cadence point but without the notes of anticipation, Example 72.b.

Example 72 a. and b.



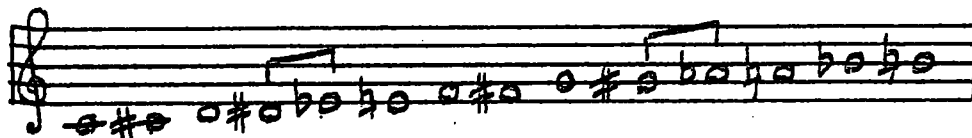
It is worth noting that the E sharp in the last example appears as an F natural in the collection of keyboard music which once belonged to Benjamin Cösyn and is now in the Paris Conservatoire. It is believed that the part of the manuscript which contains Bull's works was in his

own writing, probably compiled about 1611 before his flight to Brussels in 1613.

William Byrd. : Hexachord Fantasia. : M.B. xxviii. No.64

The Scale required is:

Example 73.



Fourteen notes are needed, but the appearance of the D sharp is very brief and ornamented. See Example 41.

The E flat is required frequently and in contexts which would render it a necessity.

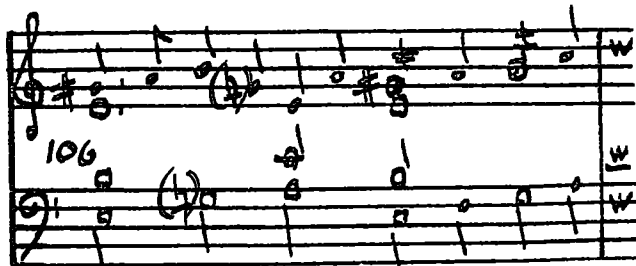
The A flat, too, makes but one appearance and is ornamented, but it is a longer note than the D sharp just quoted:

Example 74.



The G sharp is required more frequently although it is never longer than a minim and it is quite often ornamented:

Example 75.

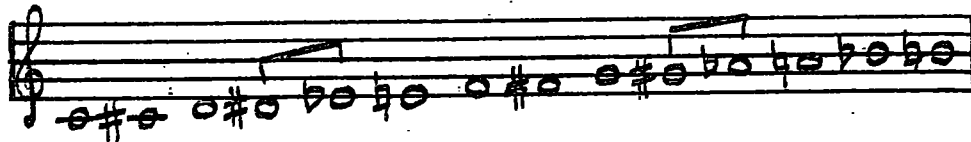


If a choice between the notes has to be made, G sharp would be preferred because of the number of its appearances.

Orlando Gibbens. : Fantasia. : M.B. xx. No.9

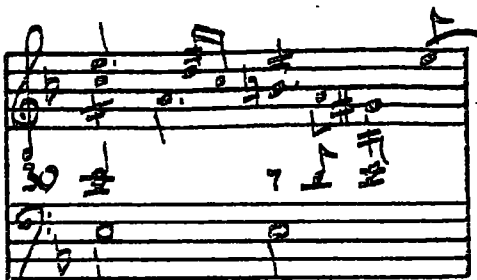
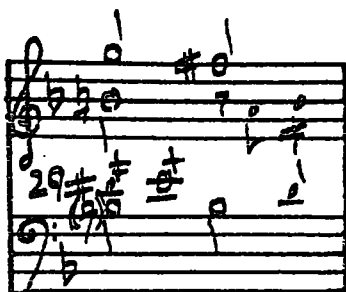
The scale required is:

Example 76.

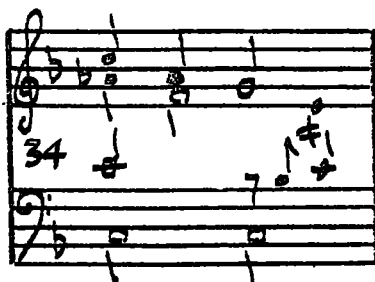


Fourteen notes are required, but the D sharp appears once only:

Example 77. a. and b.



Example 77. c.



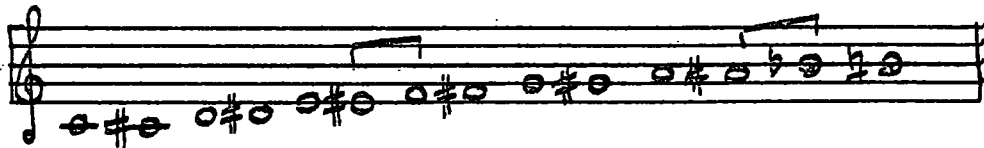
The E flat, however, is much in demand and would cause many moments of dissonance if it were replaced by a D sharp.

The G sharp makes one brief appearance disguised by an ornament (Example 77.b.)

The A flat is only needed in one bar too, but it is less easy to cover up. (Example 77.c.)

Thomas Tomkins. : A Fancy; for viols. : M.B. v. No.33

The scale required is:

Example 78.

Fourteen notes are required, and if attempted in meantone there is the added alteration of D sharp for E flat; without which the opening bars would be less than satisfactory:

Example 79. (note values halved).

The harmonic use of the D sharp is of even greater importance, and such passages as the one quoted below would suffer by having an E flat substituted for it:

Example 80.

The E sharp in bar 20 would cause an awkward moment:

Example 81.



The chord of C sharp major is not available meantime, and since this is a straight forward C sharp major chord, with the E sharp in the bass not being delayed by a suspension or ornamented, some considerable dissonance cannot be avoided.

The E sharp makes only one appearance, the F natural is required often. The case is different with the A sharp - B flat clash. Both notes are required frequently, the B flat in eight bars and the A sharp in six, the latter being more important harmonically. The most important section containing a B flat is:

Example 82.

Musical notation for Example 82, showing a complex passage with multiple staves and various notes, including a sharp sign.

but the A sharp is required in such sections as:

Example 83.

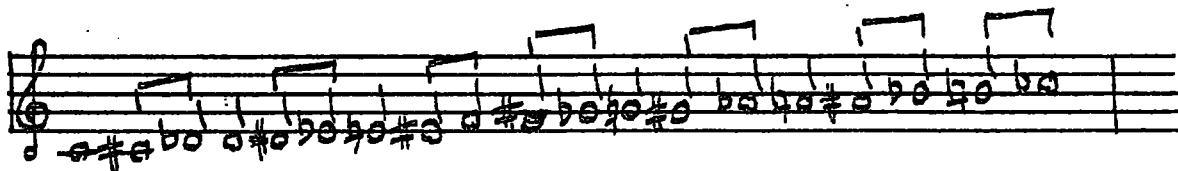
Musical notation for Example 83, showing two systems of musical notation with various notes and accidentals.

In this case the choice is difficult, but of the two the A sharp is to be preferred.

John Bull. : Hexachord Fantasia. : M.B. xiv. No.17

The scale required is:

Example 84.



Nineteen different notes are required, the only enharmonic equivalents missing, without using double sharps or flats, are F flat and B sharp. Hexachords are formed both ascending from and descending to the following notes:

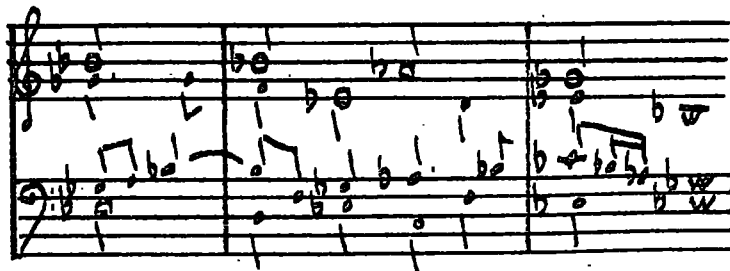
C D Flat D E Flat E F F sharp G A flat A B flat B

The chords required include:

F sharp major (b.14) B major (b.14) G flat major (b.20) E flat minor (b.20) A flat minor (b.20) D flat major (b.21) C flat major (b.21) A flat minor (b.25) F minor (b.27).

This information alone is enough to make any form of meantone impossible, and the following extract covers some of the bars mentioned:

Example 85.



The examples given in this chapter have shown some of the difficulties of thinking in terms of meantone temperament for the music under discussion. It must be borne in mind that only the difficulties have been shown, and they are confined to 78, or 13.1% of the 594 pieces

studied; 516, or 86.9% of them can be played on a standard meantone tuning without any alteration. The facts, however, must be reckoned with, and it has been the intention of this chapter to present such facts as are relevant in a study of temperament.

## CHAPTER 6.

CONCLUSION.

It is not possible to be certain about the temperament used by the English Virginalists at the distance of four hundred years, without possessing specific documentary evidence dating from the period. Such documentary evidence does not exist, but such evidence as does exist has already been presented. Whatever the temperament was, it must fit into the two broad categories of regular or irregular. Of the regular temperaments, the many forms of meantone previously described form the bulk of the available evidence, coupled with a few hints at equal temperament, the latter being mainly concerned with the tuning of fretted instruments. Of the irregular temperaments, only that of Arnold Schlick (1) comes close enough in time to be seriously considered.

One temperament which receives no documentary support in the sixteenth and seventeenth centuries is modified Pythagorean temperament. The details of setting a scale have been given, and the following extract continues the quotation from An Amateur at the Keyboard, which was begun on page 49.

We should keep in mind that from the sixteenth into the nineteenth century tuning was more variable and flexible than it is now, and the capacity of skilled musicians to detect and provide for subtle adjustments greater than at present. A comparable skill in adjusting intonation is expected of string players in chamber music today.

The tempered Pythagorean tuning is very effective for the playing of the earliest keyboard music and for English keyboard music as late as Purcell. It solves the problems of the modulations in the famous Hexachord by John Bull so effectively that, on the example of this piece alone, the use of tempered Pythagorean for English Elizabethan music seems very probable - although for a considerable part of the literature a straight Pythagorean would suffice. This would indicate that the Elizabethan keyboard music was conceived round the interval of the fifth, whereas keyboard music using a tempered just intonation (meantone) is figured more often around the interval of the third. This is not dogma but a guide to further explanation.

It may be asked why no documentation of this tuning for Elizabethan keyboard music has survived, I would point out that there is no documentation for the playing of the two commonest types of Elizabethan ornament, the single and the double line through the note stem. Apparently the composers took so much for granted the common elements of tuning and embellishment that they felt and foresaw no need to document them - as, today, no one has effectively documented jazz rhythmic notation. We who take our classical harmony for granted make the same assumption, scarcely realising that in our lifetime the very foundations of harmony are again

(1) For details of this temperament see Appendix C.

changing - if indeed, in the music of the future, any harmony as we know it will remain. (2)

The main difficulty of using modified Pythagorean temperament in a harmonic context is that the major third is very wide, wider even than that of equal temperament. In the scheme for setting the octave which is proposed in the above mentioned book, the thirds C to E and G to B would be Pythagorean thirds. If the fifth C down to F is left perfect also, there are three very common triads, C, G and F with Pythagorean thirds. These three triads alone are sufficient to make one consider the temperament unlikely at a time when theorists were striving for perfection of harmonies. The tempered fifths suggested help the chords which contain black notes, but the tempering needs to be considerable to make the Bull Fantasia playable. Whilst I would concede the point that the chords so produced will differ from each other and therefore lend a variety which equal temperament would lack, I cannot be convinced that such a group of harmonically poor chords would have been tolerated, unless the claim that Elizabethan keyboard music is conceived round the interval of the fifth can be substantiated.

This claim, on the contrary, seems to be completely at variance with the musical facts. It has already been demonstrated that the interval of a third was of considerable importance. Not only does it qualify the mode of the chord (very few chords are without it), but chords with roots a major or minor third apart are very prevalent (see page 66 ff). If such play on thirds was confined to keyboard music perhaps a case could be made that the differences in the thirds produced by the suggested modifications to Pythagorean temperament would add harmonic 'spice' to the music, but this is not so. The interplay between major and minor chords and the progression of chords with roots a major or a minor third apart are to be found in music other than that for keyboard. To make out a case for modified Pythagorean temperament on the strength of one piece, the Bull Fantasia, and then to argue from this that keyboard music was centred round the interval of a fifth rather than a third, seems to ignore too much of the evidence available.

A further weakness in the argument is that there is no reference by scholars of the period to such a temperament being used. This is explained by pointing out the lack of information about ornamentation in the music of the virginalists and suggesting that the conventions of the time would be common knowledge and therefore require no documentation. This may have been the case with ornamentation, but it was not so with

temperament. There was a great deal of interest shown by scholars in the question of temperament and a considerable amount of writing is still available to us. Keyboards with more than twelve different notes to the octave were the usual solution to problems of temperament, and information about these has already been given. Temperaments were thoroughly discussed and documented, but no reference is made to modified Pythagorean temperament as a possibility, and it seems unlikely that a temperament in current use would be completely ignored when so many others were discussed.

The characteristics of style discussed in the chapter on the music do not of themselves present a strong case for a particular temperament. They do, however, have a bearing on the subject when some of the implications of their use are studied in more detail.

Of Byrd's use of false relations in vocal music H.K. Andrews writes, "Byrd's simultaneous use of simultaneous cross relations, though generally less in extent than is generally supposed, shows much variety and an unflinching sense of contrapuntal logic." (3) His comments on another use of false relation by Byrd, namely the English cadence, are also revealing, "Byrd's use of the English Cadence is both more extensive and more varied than that of any of his predecessors or contemporaries ..... The greatest intensity is found in the English liturgical settings and the Latin motets for a large number of voices; the least in the secular madrigals and masses (in these latter no cases have been found)." The interest from the point of view of temperament is that the Church settings would probably have been accompanied by the organ. Since organs would have been meantone tuned, the harsh effects of such false relations would be quite familiar to singers, instrumentalists, composers and listeners. In a vocal composition it would be possible at such points to allow the organ to hold the basic chord and let the singers supply the false relation. This would minimise the effect but still associate it with meantone tuning. The secular madrigals would have been sung unaccompanied or in association with viols which would have been tuned to equal temperament.

From the facts already given (4), it is obvious that Byrd liked the effect of false relations on a keyboard. In his secular vocal music, which would be accompanied by viols if accompanied at all, this type of dissonance appears with least frequency. It appears, then, that in circumstances under which we might now favour such effects, they were less often found.

(3) Andrews, H.K. The Technique of Byrd's Vocal Polyphony.  
London. 1966.

(4) See page 57.

Word painting by means of chromaticism, however, was more readily available in secular compositions. The following examples from the madrigal Come wæful Orpheus, would have been difficult to accompany in meantone, and any such progressions would be impossible to contemplate solely on a meantone tuned instrument.

Example 86a.

*Some strange chro-ma-tic notes*

Handwritten musical notation for Example 86a, consisting of two systems of two staves each. The notation is highly chromatic, with many accidentals and slurs. The first system is labeled "Some strange chro-ma-tic notes".

Example 86b.

*of sour est sharps*

Handwritten musical notation for Example 86b, consisting of two systems of two staves each. The notation is highly chromatic, with many accidentals and slurs. The first system is labeled "of sour est sharps".

*and un-couth flats*

Handwritten musical notation for Example 86b, consisting of two systems of two staves each. The notation is highly chromatic, with many accidentals and slurs. The second system is labeled "and un-couth flats".

Perhaps the rather harsh effect of false relations in meantone was a consolation for the lack of harmonic flexibility. Where such flexibility was possible it was used; where it was not possible the pungency of the false relation could act as harmonic variety. As Dr. Ernest Walker says, when discussing false relations, "it does not help matters much to argue that with a system of unequal temperament they would sound a little less curious." (5) In fact, it would be very misleading to suggest they sounded "a little less curious" in unequal (meantone ?) temperament. The whole temperament sounds "curious" to modern ears with its flat thirds and sixths and large diatonic semitones (by comparison with those of equal temperament), but false relations in particular sound more intense than in equal temperament or flexible intonation.

This need not prevent the use of false relations in circumstances of flexible intonation. The 'narrow' effect of meantone false relations could be copied if so desired, but since false relations, a notable feature of his virginals music, are more prevalent in Byrd's Church music - meantone influenced - than his secular music - flexible intonation or equal temperament influenced - it can be argued that his virginals music was more likely to be meantone tempered than equal tempered.

Details have already been given about the relevance of the movement of chords with roots a tone apart, the close juxtaposing of chords with roots a major or minor third apart, and the juxtaposition of major and minor chords on the same root, to the question of temperament. It should also be mentioned that in some of the large motets of Giovanni Gabrieli, the juxtaposition of chords with roots a major or minor third apart is used purely for harmonic effect, whilst the chromatic madrigal in Italy during the period under discussion made use of juxtaposing of major and minor chords on the same root. It is interesting to speculate further on the juxtaposing of chords with roots a major third apart. In keyboard music the remoteness of such chords from each other would be much more apparent on an equally tempered instrument than in meantone or in just intonation. This remoteness is caused by two wide major thirds being superimposed on each other. The tendency in temperaments seems to have been towards a gradual sharpening of the major thirds until equal temperament was reached (except for Pythagorean temperament which was used for melodic purposes). A cursory glance seems to suggest that as the thirds became sharper so the

(5) Walker, Ernest. History of Music in England. Third Edition. Oxford. 1952.



use of major triads a major third apart became less until equal temperament was firmly established. The distance achieved by tempering the thirds then became exploitable as a means of achieving a contrast to the classical movement of chords by roots a fourth or fifth apart. Much more time would need to be spent following this idea to see whether it could stand more detailed investigation.

How much the above paragraph adds to the discussion of the temperament of early keyboards is open to question, but the subject matter of the succeeding paragraphs is fundamental to any such discussion. If meantone is to remain as a likely, or even as a possible temperament, the facts presented by pieces which contain notes other than those to be found in a standard meantone tuning cannot be ignored.

The first contentious matter concerns the retuning of instruments. Charles van den Borren's assertion that instruments were not retuned for different pieces has already been quoted, as has Alan Curtis' reminder that they could have been retuned or that different instruments could have been used. Unfortunately van den Borren does not give any authority for his statement and that of Alan Curtis is given as a suggestion rather than a fact.

Large public concerts such as those with which we are now so familiar did not exist in the late sixteenth and early seventeenth centuries. Keyboard music, other than that for organ, was in its infancy, so professional recitals would be unlikely except perhaps at private gatherings. The most likely place for the need for instrumental tuning to be felt would be in the homes of people who could afford the instruments and had sufficient leisure time to play on them. The historical tradition in keyboard playing seems to suggest it was the pastime of the ladies rather than the gentlemen of the time. Although the idea that the word virginals has anything to do with the Virgin Queen or the fact that young ladies played on the instrument has now been discredited, Queen Elizabeth was a good keyboard player, Domenico Scarlatti spent his life in the service of Princess Maria Barbara who must also have been an excellent player, and even as late as Victorian times it was still thought of as a requirement for any young lady of society. If the lady of the house or her daughters were the most likely players they would probably be unable to change the note or notes in question, and few houses would employ a keeper of instruments to be on hand to make the necessary adjustments at any time. Since it is a fairly simple matter to change an E flat to a D sharp etc., it may have been possible to have one member of the household trained to do so, but this is purely conjecture.

Instruments would also be owned by professional musicians and gifted amateurs, most of whom could easily have tuned their own instruments or at least have been able to adjust odd notes on them as required. Whether or not they did so is also a matter for conjecture, but the fact that they could easily have done so cannot be lightly dismissed. I hardly think it likely that someone who could easily alter an E flat to a D sharp would hesitate to do so if the music called for it, so I am unable to accept it as a certainty, without more positive documentary evidence to support the suggestion, that instruments were not tuned with a particular piece of music in mind. Those who could not alter the required notes would either have to play pieces which need no alteration, and most of the pieces fall into this category, or accept the faulty intonation which would result.

There is a certain amount of documentary evidence to support the views expressed above. Taking first the point of faulty intonation; the acceptable level of dissonance, even among skilled musicians, must be considered in the light of the evidence supplied in the Giles Farnaby Fantasia (6). Continual reference must be made to this quotation when the question of the tolerability of dissonance is raised. Taking next the possibility of E flat or D sharp as alternatives to each other; instruments were constructed which gave such alternatives, if the alternative was not offered by split keys it was still available by retuning, if one was capable of doing so. As to the number of pieces in which any alteration from standard meantone is required, detailed information appears elsewhere in this study, but this can be summarised by saying that of the 594 pieces studied, 516 were playable without alteration, 78 were not.

If my categories of essential, highly desirable and tolerable are accepted, from an examination of the incidence of notes not in meantone temperament, the following picture concerning the dissonances involved emerges:

in 24 pieces a change is essential;  
 in 25 pieces a change is highly desirable;  
 in 29 pieces a change of note is not necessary.

In terms of percentages of the 594 pieces studied this means:

a change is essential in	4.0% of the pieces
a change is highly desirable in	4.2% of the pieces
a change is not required in	4.9% of the pieces,

which leaves 86.9% playable without alteration.

(6) See Example 53.

In the twenty four pieces in which I have considered a change of note to be essential there are 1528 bars, only 117 of these would be strongly affected if no change was made in the notes used. The pieces in which I have suggested that a change of note is highly desirable are even less troublesome. In the twenty five pieces concerned, only 63 bars are affected, and, as pointed out in the chapter on the music, many of these could be overcome by the judicious use of ornaments. Of these in which a change of note is not really necessary very little needs to be said except that in the twenty nine pieces concerned only 42 bars are affected.

These figures bring the difficulties of using meantone temperament into proper perspective. In 594 pieces of music only 78 contain notes not available in meantone, and in the 78 pieces only 222 bars are affected, 117 of them strongly, 63 of them noticeably and 42 of them hardly at all.

If the possibility of retuning is admitted, the number of pieces affected falls steeply from 78 to 12. The twelve pieces concerned have been discussed individually already because they are not at first sight playable in meantone at all, but solutions for them will be attempted in due course. Of the 66 pieces which require one or two alterations from the standard notes of meantone, another possibility remains to be explored.

Many Italian harpsichords of the seventeenth century had split keys for certain notes other than those required for the broken octave bass. Details have already been given in the chapter on instruments. It is not without significance that the notes added to the standard keyboard were D sharp, A flat and A sharp, making keyboards of 13, 14 or 15 notes depending on how many of the extra notes were added to the instrument. Instruments which had all the extra notes would be able to play all the 78 affected pieces with the exception of the following:

John Bull.

Hexachord Fantasia  
Chromatic Galliard

M.B. xiv No. 17  
M.B. xix No. 87b.

Thomas Tomkins.

Fancy: for viols

M.B. v No. 33

If the E flat only is split, allowing a D sharp as well, 52 of the 78 pieces immediately become playable. If the G sharp is split, 17 of the pieces become playable. If both the E flat and G sharp keys are split, the 69 pieces are augmented by two more which contain both D sharps and A flats, making 71 pieces in all. The addition of an extra key for A sharp alone would not render any of the 78 pieces playable, but coupled with a split E flat key it would allow four more pieces to be added to the list. The

splitting of E flat, G sharp and B flat would therefore make 75 of the 78 pieces playable leaving only the three named above.

In the section dealing with the music, twelve pieces were classed as unplayable on a meantone temperament. Although the figures in the paragraph above show that only three of these would remain unplayable if three split keys were available, full details of the way in which all twelve can be played in meantone is given below.

Thomas Tomkins. In Nomine. M.B. v. Nos. 10 and 11.

A split E flat would render these two pieces playable in meantone, but, as already stated, very little violence would be done to the harmony if an E flat were to be used throughout, since the D sharp appears only once (Ex. 43a.). The two notes appear in different octaves so it would be possible to tune the notes required, true, but it seems unlikely that in this case it would be deemed necessary to do so and there is no documentary evidence to support any suggestion that different tunings were used in different octaves, but the fact remains that it is a possibility.

The most likely solution in the case of both of these pieces is to accept a normal meantone tuning and accept the small amount of dissonance involved.

Thomas Tomkins. Voluntary. M.B. v. No. 30.

The objections to a normal meantone tuning are the three D sharps and one A sharp. An instrument with split keys for both E flat and B flat solves the problem immediately. On a standard keyboard, the E flat can be tuned as D sharp since E flats are not required but the B flat must remain, as it is frequently used.

The one appearance of the A sharp can be ornamented if so desired, but it is so short that, if left as it is, it causes little discomfort.

The piece can be played on a standard meantone tuning which then means there are four occasions on which mistuning shows. They can all be disguised by ornamentation, but since they are each only a crotchet in length, little violence is done to the harmony by accepting them without ornamentation.

Thomas Tomkins. A Substantial Verse. M.B. v. No. 31.

The appearance of one A flat a demi-semi-quaver in length would suggest that any alteration to standard meantone temperament is unnecessary. A split key for G sharp removes even this small inconvenience.

Thomas Tomkins. The Perpetual Round. M.B. v. No. 66.

The facts about this piece are stated on page 85 and examples are given of the appearances of A flat which is required as well as G sharp. Only one A flat appears in the original (Ex. 61), another is given as an editorial addition (Ex. 62), whilst a third would appear to be necessary if the editorial A flat is accepted (Ex. 63).

Accepting all the occasions as necessary means G sharp for A flat on three occasions, two of which are a semi-quaver in length and one (the original) a quaver in length. A G sharp can easily act in place of these A flats, but again a split key for G sharp avoids these slight mistunings.

Giles Farnaby. Fantasia. M.B. xxiv. No. 8.

The extra note required is again an A flat in addition to the standard G sharp. The A flat appears in two bars and the G sharp in three, one appearance being ornamented. The G sharps are all crotchets whilst two of the A flats are a quaver in length and the third is a semi-quaver. On note lengths only G sharp appears to be the best choice, but this produces a dissonance which appears to last for three quavers. The choice, however, does not greatly affect the harmony so probably the G sharp is the note to choose. Two quaver A flats can easily be ornamented, but do little damage to the harmony if they are not, whilst a split key for G sharp resolves the difficulty completely.

John Bull. Chromatic Galliard. M.B. xix. No. 87b.

This is unplayable on a standard meantone because it requires D sharp, A sharp and E sharp, none of which can be easily replaced by its enharmonic equivalent. The full story is more clearly told by reference to Examples 70, 71 and 72 a. and b. Without split keys for E flat and B flat the only solution is to retune, and since neither E flat nor B flat is required, this simple measure leaves only the E sharp to explain. If these notes are not retuned considerable violence is done to the harmony in 11 of the 64 bars and there is a slight amount of discomfort in 3 of the others. The E sharp cannot be a retuned F because F natural is used frequently, as are E and F sharp, the only other available notes which might be retunable to provide an E sharp. An F seems the only solution and this is exactly what appears in the Paris Conservatoire manuscript. If the suggestion that this part of the manuscript is in Bull's own writing is true (7), it forms another instance of the acceptance of a level of dissonance which we would find distasteful.

(7) Dart, Thurston. Introduction to Keyboard Music of John Bull. Vol. II. and editorial note on bar 59 of No. 87b in that volume. (Musica Britannica XIX. 1963)

If meantone temperament is used, the only reasonable solution is to retune the E flat and B flat and accept the F natural as an out of tune E sharp in bars 47 and 59. For the retuning I can quote no authority, but for the F natural I can, it seems, quote Bull himself.

William Byrd. Hexachord Fantasia. M.B. xxviii. No. 64.

In this work a D sharp and an A flat are required in addition to the E flat and G sharp of standard meantone, the relevant bars are quoted as Examples 41, 74 and 75. The D sharp which appears only in bar 113 is so short that even the ornament with which it is graced could not be considered a necessity in comparison with dissonances we know to have been acceptable, although the ornament takes away some of the effect of the dissonance if an E flat - an essential note in the composition - is used instead of a D sharp. The A flat is a minim in length but appears in only one bar. If, in this case (Ex. 74), the double line ornament is taken as representing a trill, the effect of using a G sharp for the A flat is much reduced. At worst, interpreting the double line ornament as a mordent does not seriously disturb the harmony for more than about a quarter of a bar in a composition of 139 bars. This, compared with written dissonances is well within the limit of toleration. For this piece, a standard meantone tuning serves very well, and the two points at which slight dissonance occurs are brief. Split keys remove even these discrepancies.

Orlando Gibbons. Fantasia. M.B. xx. No. 9.

The notes required in addition to these of standard meantone are again D sharp and A flat. The E flat is an important note and causes much more dissonance if replaced by a D sharp than it does if used as a substitute for D sharp. In fact, the D sharp is only required in bar 29 and one of its two appearances in that bar is ornamented. An E flat is quite an acceptable substitute. The G sharp and A flat each make one appearance (Ex. 77 b. and c.) and, although the G sharp is given an ornament and the A flat is not, if the piece is attempted in meantone the proximity of the G sharp (bar 30) to the D sharp (bar 29) which would have been replaced by an E flat, suggests it is better to leave the G sharp true and use it in place of the A flat in bar 34. The alternative suggestion of retuning the G sharp to A flat and so putting both dissonances together (as they are in the manuscript version of the Giles Farnaby Fantasia previously quoted) leaves the rest of the work free from harmonic irregularities. Whichever of the two solutions is adopted the amount of dissonance involved if this piece is played on a standard meantone tuning is very small. Again, split keys for E flat and G sharp overcome the difficulty completely.

Thomas Tomkins. A Fancy : for viols. M.B. v. No. 33.

D sharp, A sharp and E sharp are required in this fancy, but since E flat is not required, the D sharp difficulty can be resolved immediately by retuning the E flat. Examples 79 and 80 refer to some of the harmonic difficulties which result if the E flat remains. The E sharp gives a poor chord on beat three of bar 20 if it is replaced by the more frequently used F natural, but this is no worse than the chord Bull accepted in the 59th bar of his Chromatic Galliard.

A much more difficult problem is presented by the choice between A sharp and B flat. When discussing the piece in the section on the music I suggested that of the two the A sharp is preferable. Neither note is a suitable substitute for the other and to express a preference for A sharp is simply to suggest the lesser of two evils rather than give a workable solution.

If split keys are acceptable or available for E flat and B flat the dissonance is then reduced to the chord on beat three of bar 20 in which an F natural does service as an E sharp.

It seems most likely that the piece was not intended for the keyboard at all. The title given in the index of the Manuscript Reserve 1122 in La Bibliotheque du Conservatoire, Paris, is Fancy for 5 viols, and Stephen Tuttle in the Textual Commentary of Musica Britannica Vol. v. says of it, "the short score version of this fancy for viols is included here only because Tomkins includes it with the keyboard pieces in Paris 1122." Although the Fancy was not originally written for keyboard, Tomkins must have thought it playable on a keyboard as it stood otherwise there is little point in his including it. The instrument on which it was played must have had a split key at least for B flat, or the resulting high level of dissonance must have been considered tolerable.

From our knowledge of eighteenth century practice we could argue that this short score was written out as a keyboard continuo part, in which case the E flat on the keyboard could be tuned as a D sharp, the original B flat of meantone retained, and, in performance, the offending notes omitted in the keyboard part and left to the viols. This, however, is not in accord with the practice of the early seventeenth century.

Bottrigari classified instruments as entirely stable, stable but alterable, and entirely alterable. In the first category he placed keyboards, in the second those with "frets or openings", and in the third "trombone, ribechini, lire, and the like." Of instruments in the first two

categories he says:

the stable and stable-alterable [instruments] cannot unite perfectly, because they sound different species (of scales), and the greatest cause of this is the difference of the semitones. (8)

These views were expressed by an Italian writer, but they may well have reflected the attitude of English musicians too. Ernest Walker, making comment on the general interest in musical matters in the early seventeenth century writes:

To a large extent this enthusiasm owed its germs to foreign influences and especially to those emanating from Italy, a country that was being more and more brought into close literary and artistic relations with England. (9)

Although the organ (stable) was used to accompany voices (entirely alterable), there is no documentary evidence to support the use of stringed keyboards, as instruments of accompaniment, and harpsichords and viols fall into the categories of stable and stable-alterable, the two categories which, according to Bettrigari, cannot unite perfectly.

John Bull. Hexachord Fantasia. M.B. xiv. No. 17.

This is the one rock on which any suggestion that all music by English Virginalists was played on a standard meantone tuned instrument must founder. No reasonable claim can be made that the piece was intended for viols and not for the keyboard, nor can its many harmonic difficulties be resolved by suggesting split keys. If this latter suggestion were made, the notes D flat, G flat, E sharp and C flat would still be left unaccounted for, because split keys were not normally fitted to more than the three notes E flat, G sharp and B flat.

This work was most likely written for one of the enharmonic harpsichords which had more than the normal twelve notes to the octave. Specific mention of these unorthodox instruments is made in the chapter on instruments. Of the instruments described, one contains exactly the nineteen notes which Bull requires for this Fantasia. The instrument is the clavicymbalum universale belonging to Charles Luytho and described in some detail by Michael Praetorius. The only other keyboard with nineteen notes to the octave is that described by Mersenne as "a perfect harmonic keyboard with nineteen keys to the octave", but this keyboard, a sketch of which is given in Mersenne (10), does not contain all the notes required by Bull, nor are they positioned in such a way that they could be readily retunable to play the notes required in this Fantasia. The instruments with more than nineteen

(8) Bettrigari, Excele. Il Desiderio. 1594.

(9) Walker, Ernest. A History of Music in England. Oxford. 1952.

(10) Mersenne, Marin. Harmonie Universelle. Paris. 1635.

Modern Translation by Roger E. Chapman,  
The Hague. 1957.



notes to the octave (e.g. the archicembalum of Trasuntino) could have been used, but the clavicymbalum universale seems the more likely both because of the notes it contained and its association with Antwerp, Charles Luython being a native of that city. The Harvard Dictionary Of Music (the entry for 'arcicembalo') states unequivocally that, "compositions such as John Bull's fantasia on the Hexachord, 'Ut, re, mi, fa, sol, la' (Fitzwilliam Virginal Book i, 183 ....) are evidently written for this instrument." Unfortunately the description it gives of the instrument that, "it had 18 keys in each octave, namely in addition to the diatonic tones - C sharp and D flat, D sharp and E flat, F sharp and G flat, G sharp and A flat, B flat, E sharp and B sharp" is one note - A sharp - short of those required to play the Fantasia. However, this is obviously a slight error because in Syntagma Musicum, which is quoted as the authority for this information, Praetorius gives, in Chapter xl, a section of musical staff showing the actual notes in each octave, together with a diagram showing the position of each note on the keyboard. The notes are nineteen in number and include an A sharp as well as the notes stated in the above quotation from the Harvard Dictionary.

Another argument in favour of the clavicymbalum universale as the instrument for which Bull wrote the Fantasia is that Bull obviously enjoyed writing music which required a considerable technique on the part of the performer. An instrument which had many more notes than a conventional keyboard presents a challenge which it is difficult to ignore. The fact that the instrument was unusual probably accounted for this being the only composition Bull wrote for it.

A further solution would be an alteration in the temperament. If so, what was the alteration? Equal temperament is the obvious conclusion. If this were the case it seems an isolated example of its use. Dr. Murray Barbour's suggestion, quoted in the introductory chapter, is also a possibility. It seems to be more than coincidence that the notes required are exactly those available on the clavicymbalum universale, but an irregular tuning for the purpose of playing this piece cannot be ruled out.

In this chapter my thoughts have been directed to explaining how a meantone tuned instrument could be made to accommodate pieces which at first sight are not playable on it. An obvious answer to the problem which eliminates all the difficulties immediately is to admit to equal temperament. A moment's thought, however, reveals this as the clarity of hind-sight, since by so doing we are ignoring the alterations in musical practice which have taken place over the period of three and a half centuries which separates us

from the music concerned. The matter of equal temperament was under discussion during the eighteenth century although it is not clearly established that the temperament was then in use. Godfrey Keller's tuning rules for harpsichord and spinet were widely circulated and were reprinted both in the appendix to William Holder's Treatise . . . . . of Harmony (London, 1731) and in Part IV of Peter Prelleur's Modern Musick Master. They are sometimes considered to refer to equal temperament, but the information given is open to various interpretations. Keller says, "Observe all the Sharp Thirds must be as sharp as the Ear will permit and all Fifths as flat as the Ear will permit. Now and then by way of Tryal touch Unison, Third, Fifth and Eighth, and afterwards Unison, Fourth and Sixth." J. Murray Barbour argues that it is impossible for the thirds to be very sharp and the fifths simultaneously very flat. In one-fifth comma meantone, where the error in fifths and thirds is equal, the error is not large. He suggests that, "Keller's rules would read better if he had said the fifths were to be only slightly flat." A closer look at the original instruction reveals that "all the Sharp Thirds must be as sharp as the Ear will permit," not all the thirds. It does, however, say "all Fifths as flat as the Ear will permit." There is no mention of a "wolf fifth", but the tuning scheme printed in the Modern Music Master clearly shows a "wolf fifth" - G sharp to E flat. It is possible that the temperament referred to is some form of irregular temperament in which all fifths except the "wolf" are flat and the thirds vary, some being sharp, and some not. Another interpretation might be that since the fifth is a more sharply defined interval than the third, the ear would permit more sharpening of the thirds than it would flattening of the fifths, in which case (ignoring the written "wolf fifth" in the tuning scheme because the change from sharps to flats must appear somewhere unless all the accidentals are written either as sharps or flats) the scheme may refer to equal temperament, or something near it. The seventeenth century does not seem to have regarded the temperament highly. The theoretical writers do not admit it as a regular temperament for keyboards although it was probably the temperament used for fretted instruments. The following quotation puts the matter very clearly:

the Clavicembale, the organ and their like sound two unequal semitones, one larger than the other. The lute and the viols sound two equal semitones, that is a tone divided into two equal semitones according to the idea of Aristoxenus. (11)

If keyboards had semitones which were unequal in size, the temperament could not have been equal temperament. This is corroborated by Salinas when he

describes quarter comma, two-seventh comma and one-third comma meantone and adds, "nor have any more as yet been thought out". The lack of written evidence in favour of equal temperament by the theorists of the day, coupled with the abundant evidence in their writings that meantone temperaments were well known and used is a strong argument against equal temperament.

Had equal temperament been a recognised temperament there would have been little need to construct instruments with more than twelve notes to the octave, a practice which had not completely died out even in 1766. A Zumpe square piano of that date, formerly owned by Sir George Smart and now owned by Messrs. Broadwood, had its black notes divided to give eighteen keys to the octave. (12). The fact that many instruments originally constructed with split keys to give alternatives to E flat, G sharp and B flat were later altered to standard twelve note octaves seems to suggest that as the sharpened third was accepted so the need for split keys became less until they were finally abandoned. There can be little doubt that the change which culminated in equal temperament was based on the acceptance of sharper thirds, and, as with most compromises, the change was gradually, almost imperceptibly, achieved. In this case it was achieved by such devices as one-sixth comma meantone and irregular temperaments. Little by little they allowed sharp thirds to become more tolerable, as well as to demonstrate the flexibility of modulation which their acceptance made possible, until criticism of them was finally silenced. But the search for enlarged harmonic horizons was not in the direction of altered temperaments in the late sixteenth and early seventeenth centuries. Their preference obviously was for altered instruments which would keep the harmonies as good as possible.

A further fact about instruments also springs to mind. The firm of John Broadwood and Sons, pianoforte makers, is still in existence. It takes its name from John Broadwood who was an apprentice to, and later successor of, Burkat Shudi, harpsichord maker. Broadwoods did not make equal temperament their standard temperament until about 1846. (13). It seems unlikely that equal temperament was standard on Shudi and Broadwood harpsichords in the eighteenth century and that Broadwoods reverted to meantone temperament when making pianos only to return to equal temperament again in 1846. It also seems unlikely that such a well known firm would be

(12) Grove. Dictionary of Music and Musicians. Fourth Edition. London. 1940. (Article on the pianoforte)

(13) Helmholtz, Hermann. On the Sensations of Tone. Section N of the English translation by A.J. Ellis. London. 1885. Reprinted New York 1954.

using meantone temperament on harpsichords at a time when equal temperament was considered standard. What is much more likely is that meantone was the standard temperament for Shudi and Broadwood and that the nineteenth century directors of John Broadwood and Sons made the change to equal temperament when it was the obvious trend in keyboard instrumental tuning.

When discussing the Bull Hexachord Fantasia, I suggested equal temperament as a possible solution. If this suggestion is accepted, the Fantasia is an isolated example of its use. Had it been the usual temperament, the obvious advantages for modulation which it offered would have been used by more composers or, at least, more often by Bull himself. If, however, the Fantasia was written (as I believe) for the clavicymbalum universale, on the grounds that such an instrument was uncommon and therefore not readily available to other musicians, the reason for the isolation of this Fantasia, because of its chromaticism, becomes clear. Equal temperament could have been available to every one with a keyboard instrument. Moreover, since sharp thirds were avoided, it seems inconceivable that a temperament based on them should be accepted for at least 593 pieces in which they were unnecessary for the sake of one piece in which they were, especially when the exact notes required to play that piece are found to be the full compass of an instrument which may well have been known to Bull through his connection with Antwerp. The existence of the clavicymbalum universale supplies for our consideration a good reason why this one piece should stand out when all the others (with the exception of the Tomkins Fancy which was admittedly for viols) can be made playable on a meantone temperament either with reference to the level of dissonance shown in the Giles Farnaby Fantasia, or by the simple expedient of altering the tuning of, at the most, three notes; even this latter expedient being unnecessary on instruments with split keys, which seem to have been fairly common.

The only remaining question is the type of meantone temperament used. All the facts point to quarter comma meantone. Firstly 86.9% of the pieces studied were immediately playable on this temperament with its advantage of true major thirds. If alteration of the tuning or split keys for E flat, G sharp and B flat are accepted, this figure rises to 98%. Of the remaining 2%, or twelve pieces, only two pieces cause any real difficulty if split keys are used, and since one of these pieces is for viols this leaves only one piece which is not playable on a quarter comma meantone tuning.

The same arguments hold good against alterations to quarter comma meantone as hold good against equal temperament. If such alterations are contemplated, they need to have the effect of equating E flat with D sharp, G sharp with A flat and A sharp with B flat. If the simple device of halving the distance between the meantones D and E, G and A and A and B is tried, it, in general, produces a great many more difficulties than it solves since it means whenever the notes E flat, D sharp, G sharp, A flat, A sharp and B flat are needed they are sure to be out of tune. As the watch which has stopped is sure to show the correct time at least twice a day, whilst the one which gradually gains or loses never shows the correct time unless it is reset, so a temperament which has the set notes E flat, G sharp and B flat and ignores D sharp, A flat and A sharp will more often than not be correct for the music I have studied. If more sophisticated methods of tempering are attempted the result will inevitably be the sharpening of more thirds than is necessary just to alter the three main obstacles to quarter comma meantone, namely the absence of alternatives for E flat, G sharp and B flat without split keys or retuning. Contemporary theorists do not offer solutions in the form of irregular temperaments, these do not appear until later (even Praetorius does not mention the Schlick temperament) and it must be a matter for conjecture only whether such compromises were available as early as the lifetime of Bull or Byrd. With irregular temperaments the aim was to close the circle of fifths and yet retain the most used thirds as pure as possible, but the compositions I have studied do not require a complete circle of fifths or even a large part of it and so, again, the cure is worse than the disease if other forms of meantone than quarter comma are used.

The harmonic freedom enjoyed in music not requiring a keyboard, as well as in some of the keyboard pieces already discussed, was a temptation which could not be long resisted. By the end of the seventeenth century the Werckmeister temperaments were in print and probably also in use. Without the compromises presented by such irregular temperaments, J.K.F. Fischer's Ariadne Musica (1702 and 1715), which uses nineteen keys, and Bach's Das Wohltemperierte Clavier (1722 and 1744), which uses all twenty-four keys, would have been unplayable unless equal temperament was in use as early as the beginning of the eighteenth century. "The development of an idiomatic harpsichord style" (14), a style which was to influence later keyboard music, was one of the most important features of the English

(14) Kirby, F.E. A Short History of Keyboard Music. New York. 1966.

virginalists' music, but, as surely as these seeds which were to flower in the keyboard works of the Baroque were present in this music, so also were the seeds which were to destroy the temperament best suited to its performance.

APPENDICES

- Appendix A.           Definitions of some of the terms used.
- Appendix B.           Details of some regular Meantone temperaments.
- Appendix C.           Details of some irregular Meantone temperaments.
- Appendix D.           Some information about Equal temperament.
- Appendix E.           Table of comparisons of four temperaments - equal  
temperament, quarter comma meantone temperament,  
just temperament and Pythagorean temperament.
- Appendix F.           Information, in figures, about the number of works  
studied and the notes used.

The figures quoted in appendices A - E are taken from:

- Barbour, J. Murray.    Tuning and Temperament.  
East Lansing 1951.
- Apel, Willi.            Harvard Dictionary of Music.  
2nd Edition. London 1970.

APPENDIX A.Definitions of some of the terms used.

Cent.	1/100th part of an equal tempered semitone.
Circulating Temperaments	Temperaments in which all keys are playable, but those in which there are fewer sharps or flats are better.
Closed System	A regular temperament in which the initial note is eventually reached again.
Diatonic Comma	The interval by which 12 perfect fifths exceed 7 octaves, or, the interval between two enharmonically equivalent notes in Pythagorean tuning. Its ratio is $531441 : 524288$ or approximately $74 : 73$ . It is equal to 23.5 cents, conventionally taken as 24 cents. (Also Comma of Pythagoras)
Exponents	Used to indicate deviation from Pythagorean tuning, the unit being the syntonic comma. Plus values indicate the note is sharper and minus values that it is flatter than the corresponding Pythagorean note. Fractional exponents indicate subdivisions of the comma as in meantone and many irregular temperaments.
Great Diesis	The interval by which 4 true minor thirds exceed one octave. It is equal to 63 cents.
Just Intonation	A system of tuning based on the octave (2 : 1) the pure fifth (3 : 2) and the pure major third (5 : 4).
Minor Diesis	The interval by which an octave exceeds 3 pure major thirds. It is equal to 41 cents.
Schisma	The interval by which 8 perfect fifths and a major third exceed 5 octaves, or, the difference between the ditonic and syntonic commas. Its ratio is $32805 : 32768$ and it equals approximately 2 cents.
Syntonic Comma	The interval by which 4 perfect fifths exceed 2 octaves and a major third, or, the interval between a just major third (5 : 4) and a Pythagorean major third (81 : 64). Its ratio is $81 : 80$ and it equals 21.5 (conventionally 22) cents. (Also Ptolemaic Comma and Comma of Didymus).
Temperament	A system, some of whose intervals cannot be expressed in rational numbers.
Tuning	A system, all of whose intervals can be expressed in rational numbers.
Wolf fifth	The dissonant fifth, usually G sharp to E flat (written as a diminished 6th), in any unequal temperament, such as the meantone wolf fifth of 737 cents.



In appendices B and C the number of cents given below each note name shows how that note compares with its equivalent in equal temperament. Since, according to the Harvard Dictionary, a sensitive ear can detect a movement in pitch of about six cents, in  $1/6$  comma temperament, E flat is 305 cents as against 300 cents for equal temperament, the difference of 5 cents is just about discernible, the C sharp, however, is 11 cents short of the 100 cents of equal temperament, a difference which would be easily discernible.

APPENDIX B. Details of some Regular Meantone Temperaments.

Aron's 1/4 Comma Meantone Temperament.

Details of the temperament first appeared in Toscanelle in Musica, Venice 1523, revised 1529.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	76	193	310	386	503	579
<u>Note</u>	G	G sharp	A	B flat	B	C	
<u>Cents.</u>	697	773	890	1007	1083	1200	

Zarlino's 2/7 Comma Temperament.

Details of the temperament appear in Institutione armoniche, Venice 1558.

<u>Note</u>	C	C sharp	D	E flat	E	F	
<u>Cents.</u>	0	70	191	313	383	504	
<u>Note</u>	F sharp	G	G sharp	A	B flat	B	
<u>Cents.</u>	574	696	817	887	1008	1078	

Salinas' 1/3 Comma Temperament.

Details appear in De Musica Libri vii.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	64	190	316	379	505	569
<u>Note</u>	G	G sharp	A	B flat	B	C	
<u>Cents.</u>	695	758	884	1010	1074	1200	

1/5 Comma Temperament. (Verheyen, Rossi).

Details appear in Rossi's Sistema Musico, Perugia 1666.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	83	195	307	390	502	586

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	698	781	893	1005	1088	1200

Rossi's 2/9th Comma Temperament.

Details appear in Sistema Musico.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	79	194	308	389	503	582

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	697	777	892	1006	1085	1200

Silbermann's 1/6 Comma Temperament.

Information appears in Georg Andreas Sorge's Gesprach zwischen einem Musico theoretico und einem Studioso musices, Lobenstein 1748.

The figures given below were worked out by J. Murray Barbour from Sorge's comments.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	89	197	305	394	502	590

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	698	787	895	1003	1092	1200

APPENDIX C.      Some Irregular Meantone Temperaments.

Meantone Temperament with Two Sharp Fifths.

This temperament is an attempt to diminish the effect of the wolf fifth by dividing the excess sharpness (35 cents) between C sharp - G sharp, and, G sharp to E flat. It is generally, but erroneously, attributed to Schlick, and, according to Ellis, was still in use in England in the early nineteenth century.

<u>Note.</u>	C	C#	D	E <sup>b</sup>	E	F	F#	G	G#	A	B <sup>b</sup>	B	C
<u>Cents.</u>	0	76	193	310	386	503	579	697	793	890	1007	1083	1200

Mersenne's Improved Meantone Temperament No.1.

Details appear in Harmonie Universelle; the fifths E flat to B flat, and B flat to F are pure.

<u>Note</u>	C	C#	D	E <sup>b</sup>	E	F	F#	G	G#	A	B <sup>b</sup>	B	C
<u>Cents.</u>	0	76	193	299	386	503	579	697	773	890	1001	1083	1200

Rameau's Modified Meantone Temperament.

Details appear in Rameau's Nouveau Systeme de Musique theorique, Paris 1726. Although historically important for his advocacy of equal temperament, Rameau still said of temperaments that, "the most perfect of all" is that in which "the fifth is diminished by the 1/4 part of a comma", but to get rid of the flatness, by a minor comma (2025/2048), of G sharp, he suggested that some of the fifths be tuned more just to regain the lost minor comma.

<u>Note</u>	C	C#	D	D#	E	F	F#	G	G#	A	B <sup>b</sup>	B	C
<u>Cents.</u>	0	87	193	298	386	503	585	697	789	890	1007	1083	1200

Werckmeister Temperaments.

Details of these temperaments appear in Musicalische Temperatur, Frankfurt and Leipzig, 1691.

Werckmeister's Correct Temperament No.1. (1/4 comma)

This, the most famous of his temperaments, divides the comma equally among four fifths C - G, G - D, D - A and B - F sharp.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	90	192	294	390	498	588

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	696	792	888	996	1092	1200

Werckmeister's Correct Temperament No.2. (1/3 comma)

This temperament contains five fifths flat by 1/3 of a comma, two fifths sharp by 1/3 of a comma and five perfect fifths. This is the poorest of the three temperaments.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	82	196	294	392	498	588

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	694	792	890	996	1094	1200

Werckmeister's Correct Temperament No.3. (1/4 comma)

Five fifths, D - A, A - E, F sharp - C sharp, C sharp - G sharp, and F - C are flattened by 1/4 of a comma, and one fifth G sharp - D sharp is raised by 1/4 of a comma in this temperament.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents.</u>	0	96	204	300	396	504	600

<u>Note</u>	G	G sharp	A	B flat	B	C
<u>Cents.</u>	702	792	900	1002	1098	1200

Arnold Schlick's Temperament.

Details of this temperament are to be found in Tablaturen etlicher Lobgesang und Lidlien, Mainz 1512, reprinted in Monatshefte fur Musikgeschichte, i (1869) and also in Spiegel der Orgelmacher und Organisten, Mainz 1511, and reprinted, as above, in Monatshefte fur Musikgeschichte.

Schlick seems to have been the first writer to describe a temperament for each note of the chromatic scale, but the idea that he founded the meantone system cannot be sustained. Shohe Tanaka, in Vierteljahrschrift fur Musikwissenschaft, vi, (1890), spoke of Schlick's "exact instructions" and added, "In exact language this will mean that each fifth is to be flattened by 1/4 comma." In fact, Schlick gave very indefinite rules.

Beginning with F, the fifth F - C is to be tuned somewhat flat, similarly with the other 'claves naturales', tuning by fifths and making all the octaves perfect. Of the major thirds he says, "although they will all be too high, it is necessary to make the three thirds C - E, F - A, and G - B better .....as much as the said thirds are better, so much will

G sharp be worse to E and B."

Tuning the black keys is a similar process, tuning upwards by flat fifths from B to F sharp then C sharp and downwards from F to obtain B flat and E flat. The G sharp needed as third above E was also the A flat a third below C, Schlick suggests that the A flat - E flat fifth be somewhat larger than a perfect fifth.

The system cannot have been meantone, but rather, some irregular system lying somewhere between meantone and equal temperament. J. Murray Barbour's attempted reconstruction makes its diatonic fifths 698 cents (1/6 comma tempering), the chromatic fifth 700 (as equal temperament) and his two sharp fifths 706 cents. His diatonic thirds will be 6 cents sharp, his chromatic thirds 8 or 10 cents sharp, the thirds E - G sharp and A flat - C, 18 cents sharp and D flat - F, B - D sharp and F sharp - A sharp, the 'foreign thirds', 26 cents, or slightly more than a comma, sharp. The attempted reconstruction is shown below.

<u>Note</u>	C	C sharp	D	E flat	E	F	F sharp
<u>Cents</u>	0	90	196	302	392	502	590
<u>Note</u>	G	G sharp	A	B flat	B	C	
<u>Cents</u>	698	796	894	1002	1090	1200	

APPENDIX D.Some Information about Equal Temperament.

If the temperament is set exactly, each semitone should contain 100 cents, as follows.

<u>Note.</u>	C	x	D	x	E	F	x	G	x	A	x	B	C
<u>Cents.</u>	0	100	200	300	400	500	600	700	800	900	1000	1100	1200

There have, however, been many approximations to equal temperament, two of the most notable being by Mersenne. The details of these temperaments appear in Harmonie Universelle, Paris, 1636-7.

Mersenne's First Geometrical Approximation.

<u>Note.</u>	C	x	D	x	E	F	x	G	x	A
<u>Cents.</u>	0	100.4	200.9	301.3	401.8	501.6	601.3	701.1	800.9	900.6

<u>Note.</u>	x	B	C
<u>Cents.</u>	100.4	1100.2	1200

Mersenne's Second Geometrical Approximation.

<u>Note.</u>	C	x	D	x	E	F	x	G	x
<u>Cents.</u>	0	102	203	305	407	508	610	712	814

<u>Note.</u>	A	x	B	C
<u>Cents.</u>	910	1007	1103	1200

For fretted instruments, three possibilities existed; equal temperament - twelve equal semitones - was accepted by Zarlino, Salinas and Galilei: a temperament with ten equal semitones and two smaller semitones was accepted by Grammateus and Bermudo, whilst a temperament of ten equal semitones and two larger ones was accepted by Artusi and probably by Bottrigari and Cerone too.

APPENDIX E.Table of Comparison of Four Temperaments: Equal, Quarter Comma Meantone, Just and Pythagorean.

<u>NOTE NAME</u>	<u>EQUAL TEMP.</u>	<u>QUARTER COMMA MEANTONE</u>	<u>JUST</u>	<u>PYTHAGOREAN</u>
C	0	0	0	0
C Sharp	100	76	70	114
D Flat	100	117	112	90
D	200	193	182 Min.) 204 Maj.) Tone	204
D Sharp	300	269	253	318
E Flat	300	310	316	294
E	400	386	386	408
F	500	503	498	498
F Sharp	600	579	568	612
G Flat	600	621	610	588
G	700	697	702	702
G Sharp	800	773	772	816
A Flat	800	814	814	792
A	900	890	884	906
A Sharp	1000	966	954	1020
B Flat	1000	1007	996	996
B	1100	1083	1088	1110
C	1200	1200	1200	1200



APPENDIX F. Information, in figures, about the Number of Works Studied and the Notes used in them.

1. Number of Pieces Studied and their Sources.

Since some of the works which appear in the collections are also to be found in the complete works of particular composers, the figures in brackets indicate the number of pieces in the collection and the number which had to be subtracted because they are included elsewhere in the list.

Fitzwilliam Virginal Book Vol. 1	53	(109 - 56)
" " " Vol. 2	64	(188 - 124)
Complete Works of Tomkins. M.B.v.	73	
" " " G. & R. Farnaby. M.B.xxiv	58	
" " " Bull. Vol.1 M.B.xiv	61	
" " " Bull. Vol.2 M.B.xix	104	
" " " Byrd. Vol.1 M.B.xxvii	59	
" " " Byrd. Vol.2 M.B.xxviii	63	
" " " Gibbons. M.B.xx	50	
" " " Tisdall	2	(7 - 5)
Clement Matchett's Book	7	(12 - 5)
	<hr/>	
	594	
	<hr/>	

2. Pieces which include all Twelve Notes of the Meantone Scale.

Thomas Tomkins	10
Giles Farnaby	3
William Byrd	3
Orlando Gibbons	2
John Bull	16
Fitzwilliam Virginal Book	<u>3</u>
	<hr/>
	37
	<hr/>

Pieces included in the above list but have one of the standard notes of the meantone scale altered.

Giles Farnaby	1	A sharp for B flat
Orlando Gibbons	1	D sharp for E flat
John Bull	8	D sharp for E flat
John Bull	2	A flat for G sharp
	<hr/>	
	12	
	<hr/>	

3. Pieces which can be played Meantone with the alteration of one note.

a. D sharp for E flat.

Thomas Tomkins	13
Fitzwilliam Virginal Book	7
Giles Farnaby	1
William Byrd	4
Orlando Gibbons	10
John Bull	12
	<hr/>
	49
	<hr/>

b. A flat for G sharp.

Thomas Tomkins	2
Fitzwilliam Virginal Book	5
William Byrd	5
John Bull	2
	<hr/>
	14
	<hr/>

4. Pieces which can be played Meantone with two notes altered:

D sharp for E flat and A sharp for B flat.

Fitzwilliam Virginal Book	1
Giles Farnaby	2
	<hr/>
	3
	<hr/>

5. Pieces which are not playable on a Meantone temperament.

Thomas Tomkins. M.B.v	6	Nos. 31, 33, 66, 10, 11, 30
Giles Farnaby. M.B.xxiv	1	No. 8
William Byrd. M.B.xxviii	1	No. 64
Orlando Gibbons. M.B.xx	1	No. 9
John Bull. M.B.xiv and xix	3	Nos. 17, 38, 87b.
	<hr/>	
	12	
	<hr/>	

The above twelve pieces all have 13 or more notes to the octave, and one (Bull No.17) has nineteen different notes to the octave.

6. Some of the above figures reduced and then expressed as percentages.

Of the 594 pieces checked,

- 516 were playable meantone without alteration.
- 63 were playable meantone with one alteration.
- 3 were playable meantone with two alterations.
- 12 were not playable meantone.

Expressed as percentages this means that approximately:

- 86.9% were playable meantone without alteration.
- 10.6% were playable meantone with one alteration.
- .5% were playable meantone with two alterations.
- 2.0% were not playable meantone.

or:

- 98.0% were playable on a scale with twelve different notes to the octave.
- 2.0% needed more than twelve different notes to the octave.

Of those which required alteration:

- 8.3% required D sharp for E flat.
- 2.3%—required A flat for G sharp.
- .5% required D sharp for E flat and A sharp for B flat.

Of the 66 pieces which required alteration:

- 15 were by Bull.
- 15 were by Tomkins.
- 14 were from the rest of the Fitzwilliam Virginal Book.
- 10 were by Gibbons.
- 9 were by Byrd.
- 3 were by G. Farnaby.

Of the 12 pieces not playable meantone:

- 6 were by Tomkins.
- 3 were by Bull.
- 1 was by Byrd.
- 1 was by G. Farnaby.
- 1 was by Gibbons.

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All the musical examples in this dissertation have been taken from the above sources. Editorial alterations have been indicated in red.