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The next issue, Quarterly 113, will appear in August 2009. Please send in Comms and announcements to the address below, to arrive by August 1st.

Fellowship of Makers and Researchers of Historical Instruments

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Well, we have made it this far. We have produced four issues of the Quarterly including this one, since the revival begun last year, so in a very basic sense we have discharged our debt to those who paid a full year’s subscription in before the six-year hiatus in publication. But of course that is not the point! It is a little worrying that this issue is a bit slimmer than the last three, and there has been no need to hold back material for the August issue. So please, while sunning yourself on the beach over the holidays, do mull over any organology questions you have had in your mind for a while that might be turned into a Comm. Only YOU can make FoMRHI continue to prosper.

Everything always takes longer than you think. This issue will have landed on your doormat in June, not the cover date of May, and I had hoped to issue subscription renewal forms herewith, and to announce the establishment of a website, with facilities for subscribing online, and view or download pre-2001 Qs – the obvious way of making all the painstaking researches carried out in previous decades available to instrument enthusiasts everywhere. I hope to be able to do these things in the next issue.

Members’ announcements are always welcome – if using a computer, please send these as plain text emails, rather than attachments.

Keep those Comms coming!

Where are they now? Over six years our address database has got a bit out of date. Does anyone know the whereabouts of Krzysztof Kulis. He paid his subscriptions along with everyone else, and is entitled to receive FoMRHIQ; recent correspondence has been returned by the Post Office. Many thanks to all of you who have given information so far, including news of those who have gone to mix their music with that of the angels.

Email addresses, please! If you haven’t received any emails from us this year, that means we don’t have your email address. It makes communication so much easier if we have it. We promise not to send out any spam, or pass it on to anyone else. Please send a brief message to Lutesoc@aol.com, and we can add you to our list.
STANDING CALL FOR PAPERS

The Fellowship of Makers and Researchers of Historical Instruments welcomes papers on all aspects of the history and making of historical musical instruments. Communications or ‘Comms’ as they are called, appeared unedited (please don’t be libellous or insulting to other contributors!), so please send them EXACTLY as you wish them to appear – in 12 point type, on A4 paper with a 25mm or 1 inch border all round, or to put it another way, if you are using non-European paper sizes, then the text area must be 160 x 246 mm (or at least no wider or longer than this). Our printers usually make a reasonably good job of scanning photos.

You can send contributions EITHER on paper, OR as a Word-compatible or PDF attachment. If you really do not have access to a word processor of any kind, we may be able to retype typed or handwritten submissions.

NOTE OUR NEW ADDRESS:

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and the email address for Comms sent as attachments (and other email correspondence) is Lutesoc@aol.com

Non-members will be given a year’s free subscription if they send in a Communication to the Quarterly.

If you ever sent in a paper (in the last 6 years) for the Quarterly, and it never appeared, please re-send it, to the new address.

There are plans to scan back issues of the Quarterly and make them downloadable from a website, to be set up; in the meantime you can obtain back issues for the princely sum of £3 per issue, including postage; send a cheque payable to FoMRHI, at the above address, or write with your credit card details.

If your interests have changed, and you don’t now want to be a member of FoMRHI, please let us know, to save postage costs.
MEMBERS' ANNOUNCEMENTS

Classical handmade guitars and one steel string. At cost price. Spruce fronts, Indian rosewood backs and sides, ebony fingerboards, oiled finish. Made with great enjoyment by me. Call Mike, on 01702 556892 (Southend area).

Jan Bouterse’s dissertation about Dutch woodwind instruments and their makers, 1660-1760, has been translated and published in English language at: http://home.hetnet.nl/~mcjbouterse/inhoud&samenvatting.htm; also http://www.kvnm.nl/current/03Catalogus/BN_9.htm, with English summary. He is on the point of finishing a (thick) manual on making woodwind instruments, incorporating his experience gained from research into historical instruments, though this is currently in Dutch only.
Contact: Jan Bouterse, Sandenburg 69, 2402 RJ Alphen a/d Rijn, Netherlands tel. + 31 172 445957 e-mail: mcjbouterse@hetnet.nl

The Viola da Gamba Society’s Thematic Index of Music for Viols has now been added in its entirety to the web-site (www.vdgs.org.uk) and comprises all additions and corrections to November 2008. In future it is intended to update the work annually. Some of the files are large and will be split into smaller units at the next up-date. Copies on CD-ROM can still be made for those who would prefer this format.

Volume II of The Viola da Gamba Society Journal, edited by Peter Holman, is now available on-line. Contents are:
(1) ‘The Nomenclature of the Viol in Italy’ – Bettina Hoffmann, translated by Richard Carter and John Steedman;
(3) ‘Laurence Sterne the Musician’ – Peter Holman;
(4) ‘Laurence Sterne, Charles Frederick Abel and the Viol’ – Claire Berget
Reviews: The Viola da Gamba Society Index of Manuscripts, vol. 2 (David Pinto);
Mary Cyr, Essays on the Performance of Baroque Music (Susanne Heinrich);
William Lawes, The Harp Consorts (PRB Viol Consort Series, no. 62) (John Cunningham)

The editor of Volume III (to be published at the end of 2009) will be Richard Carter, Bahngasse 11, A-3420 Kritzendorf, Austria (e-mail: johanna.richard@utnet.at). A theme will be viol music in tablature, although papers on other subjects are also invited; please contact him or the General Editor, Andrew Ashbee (e-mail: aa0060962@blueyonder.co.uk). A style sheet has now been compiled, and is available on the Society’s website.

Andrew Ashbee
IX INTERNATIONAL CLAVICHORD SYMPOSIUM

16 – 19 September 2009

– HAYDN and the Clavichord
– From Clavichord to Fortepiano

History, inventory and characteristics of known extant instruments, iconography, social and musical role, present state of instrument building

Concerts will be held in the evening and shorter recitals will complement the morning lectures.

A display of instruments, original or copies, will be held in the Chiesa di Santa Marta.
Errata in Comm 1858

Some of the names in Comm. 1858, John Weston’s review of *Modern Clavicord Studies: De Clavicordio VIII* were regrettably misprinted, ‘Uta Kenning’ should have read ‘Uta Henning’, ‘Alfons Uuber’ should have read ‘Alfons Huber’, and ‘Dorothea Demee’ should have read ‘Dorothea Demel’.
Mortua dolce cano – an answer to Comms 1848, 1849

In response to John Downing’s query as to the source of the verse ‘Viva fui in silvis . . . Mortua dolce cano’, it is found, apparently in full, on the fingerboard of a viol by Kaspar Tieffenbrucker in the Gemeentemuseum in the Hague; according to Rene Clemencic, *Old Musical Instruments* (Weidenfeld and Nicholson, English trans. 1968; fig. 52, p. 52 in my edition).
Bouwerskontakt and its publications

Bouwerskontakt ist the Dutch sister association of the FoMRHI. Bouwerskontakt started in 1975 as a section of Huismuziek (society for amateur music making) and has now about 500 members. Currently the most active subsections (bouwgroepen) of Bouwerskontakt are those of the makers of guitars (and other plucked instruments), string instruments, the house organs and the small barrel organs. The sections involved with woodwinds, bagpipes & hurdy-gurdies and harpsichords (with clavichords etcetera) are smaller. Most sections have regular meetings, in the city of Arnhem where Bouwerskontakt has its own workshop. Here is also a library with books, periodicals and several sets of drawings. The Bouwbrief is our quarterly magazin, with a wide variety of articles about all kinds of musical instruments. All issues of the Bouwbrief from 1975 to 2006 are now available on a DVD-ROM (30 euro).

Bouwerskontakt is also selling several drawings of instruments and instructions how to make them. One of those is a book in English language: the Small Barrel Organ, building instructions by Johan de Vries (No. 9404, 18 euro). Some other publications (all of them in Dutch language):
- Small chamber organ (positieforgel) by Johan de Vries (book, No. 9406: 21 euro)
- House organ with one manual (éénklaviers huisorgel) by Simons (3 drawings with building instructions, No. 9402: 30 euro).
- Chest organ (kistorgef) by Peter Hoogerheide (map with 17 drawings, photos and description, No. 9405: 80 euro)
- Clavichord (C.G. Hubert 1787), by Gerrit Menkveld (drawings, No. 9302: 40 euro)
- 'Travel clavichord' (Reis-clavichord, J.A. Stein 1787), by Gerrit Menkveld (drawings, No. 9303, 40 euro). All prices excl. postage and packing.
You can place your orders via Bureau Huismuziek, Postbus 9, 6800 AA Arnhem, Netherlands. E-mail: info@huismuziek.nl.

Photo: small barrel organ, made by one of the members of Bouwerskontakt
'Now and then I make mistakes myself'.
(Cecil Torr, 'Small Talk at Wreyland', 1918, p.110)

Thomas Munck justly castigates me for carelessness (not, I assure him, 'careful omission') in checking the original text of Praetorius, and I very much regret that I wrongly charged him with deliberate falsification of evidence; though having said that I remain of the opinion that his brief version of the passage in question is unacceptably biased for readers of 'The Viol' (just what is the 'disagreement' which P. 'recognises'?), and that this error of mine does not weaken the case which I have made against the so-called 'meantone fretting' of lutes and viols in the least. Our business however is not scoring debating points but attempting to arrive at factual historical truth.

Thomas suggests that a) practice in Britain may have been different from that of Praetorius; b) Praetorius may have been ill-informed on practice in Britain; and c) the clash of temperaments between keyboards and viols tolerated by Praetorius would not have been tolerated for 'intimate consort playing (especially if accompanied by a pipe organ)'. Comments:

a) Maybe, but conjecture - 'creative thinking' - is not evidence. For Italy there is good evidence that practice in 1594 was that of Praetorius. In Bottrigari's 'master and pupil' treatise 'Il Desiderio' (ref. 5 of my Comm. 1827) the 'Master' Benelli tells us (p. 6) that '...il Clavacembalo, l'Organo, & simile suonano due semituoni ineguali, ciò è uno maggior re dell'altro, et che il Lauto, et le Vuole suonano due semituoni eguali, ciò e il Tuono diviso in due semituoni eguali secondo la mente di Aristosseno.' He seems concerned to make this quite clear, for there is on p. 7 a further marginal note 'Clavacembalo, & Lauto perche non si possono accordare insieme perfettamente'. I know of no verbal or pictorial evidence that practice was different in Britain.

b) Praetorius was by no means ignorant of what British players did (e.g. 'small cittern' - and his frustratingly obscure statement about the pitch they used). British players were well-known and esteemed on the Continent; Italians were well-known and esteemed in Britain. So this is another 'maybe'; and, bearing in mind the evidence of pictures, I think it unlikely that fretting practice in Britain differed from that in Germany and Italy.

c) If viols could be fretted in genuine meantone, and if there were some evidence (pictorial or textual) that fretting patterns changed with tunings (even the orthodox tenor and bass frettings being so very different in MT) there might perhaps be something in this suggestion. But they cannot be, and there is no such evidence. 'Meantone fretters' are conspicuously reluctant to face up to this problem. They have not only to assume that it was so well known and variable unequal fretting so much a matter of course that no writer (Ganassi-Bottrigari-Praetorius-Mace-Simpson-Playford among them) even hints at it, but to explain why artists quite often show us ET fretting, sometimes very accurately, whereas we have to look very hard for any picture which can plausibly be offered as evidence of approximation to MT and none of course shows a genuine MT pattern. It defies belief.

Thomas, by his own account, is one of those who 'choose to move their frets about in the belief that the resulting sound is better', as he has every right to do. But, I repeat, he is not achieving a mean-tone tuning, and to call it so is to assume the privilege of Humpty Dumpty - 'When I use a word it means what I want it to mean'.

For the rest - I am quite content to be judged by open-minded readers who will study carefully all the available evidence, as I have attempted to do - not just bits of it. I cannot be expected to bother with those who will not do so.
Thanks to Julian Goodacre for drawing our attention to David Hockney’s book “Secret Knowledge” (Comm. 1838) in which the author presents his ideas about how optical apparatus may have been used as drafting aids by some early European painters. The book makes fascinating reading and is beautifully illustrated with many clear and detailed images of the paintings used as examples in support of Hockney’s arguments. Hockney, however, is not alone in his investigations as there are many others currently researching this interesting branch of the history of science (1).

One of the examples used by Hockney is the early 16th C. painting “The Ambassadors” by Hans Holbein (2). Hockney does not provide an in-depth analysis but notes that the painting appears to be a collage constructed from smaller images – each very precise in their detail, as if made with the aid of an optical projection device – yet unrelated in their perspective. For example, on the lower shelf in the painting, two books in front of the lute, all convincingly portrayed, in fact have differing perspective ‘vanishing points’ suggesting that the images may have been made with the aid of a mirror-lens projection device. Not mentioned by Hockley, but central to his idea confirming use of optical apparatus, is the powerful light source that must have been used to illuminate the subject matter in the painting as evidenced by the strong highlight at the front edge of the lute and the shadows cast by the lute and the pegs etc. As for the lute, Hockney suggests that, as it is represented in much simpler foreshortening (compared to the other more complex spherical objects in the painting), it could have been drawn using an ‘Alberti grid’ like those depicted in the well-known woodcuts by Albrecht Durer.

However, the image of the lute, upon closer examination, would appear to suffer from faulty perspective if judged by Alberti’s single vanishing point convention – well understood and used by Holbein in his time. The vanishing point of the bridge, neck joint and frets #1 to #4 coincide but that defined by the pegbox bottom edge and nut do not (and neither do the projections of frets #5 to #8). Furthermore, the strings are not straight but are drawn curved along their length. These deviations from the Alberti perspective geometry, create the illusion of an instrument that is curiously curved and twisted. Could these discrepancies be accounted for if some kind of optical aid was employed to draw the books and lute as a group rather than separately? Experiments with mirror-lenses and
other early optical projection devices indicate that it is sometimes necessary to move the apparatus in use in order to obtain clearer images from the simple mirrors or lenses that must inevitably suffer from optical aberrations. These adjustments may result in the creation of several perspective vanishing points in a finished painting. This being the case, Holbein may have found it necessary to reposition his optical projection apparatus (if indeed he was using such a device) at least four times in the course of creating the outlines of the lute and the books – resulting in separate vanishing points for each of the books and two or more for the lute.

Given the uncertainty surrounding the perspective of the lute image and how it was generated, any effort to create a true profile of the lute, by a process of reversing and transposition of the perspective geometry of the image as a whole, is unlikely to succeed and so will remain open to opinion and speculation (3).

Some recent work by a fellow researcher, using computer 3D graphics software to manipulate the image, suggests that the true profile of ‘The Ambassadors’ lute may be close, if not identical to the Arnault de Zwolle lute geometry. Computer 3D software can accurately generate perspective views of a volume (such as that given by the Arnault lute geometry), so it might be possible to replicate Holbein’s distorted image of the lute by using the ‘collage’ technique that Hockney suggests was employed by the artist. This possibility could be tested by creating separate computer generated images of the pegbox, neck and bowl/soundboard – each with their differing perspective vanishing points – and by blending them together to form the final image.

An alternative low tech. approach might be to construct a three dimensional model of the Arnault lute (with suitably shortened neck etc.) and attempt to precisely recreate, by a process of trial and error, the distorted image drawn by Holbein using a mirror-lens, camera obscura or other appropriate early optical projection apparatus. Success in these investigations would help to confirm not only the type of optical device that may have been used by Holbein and the method he employed in its use but might also confirm, once and for all, the true geometry of the lute.

Notes
(1) A collection of research papers, presenting an in depth study of early optical projection devices, their design, construction and use “Inside the Camera Obscura – Optics and Art under the Spell of the Projected Image”, Preprint 333, Wolfgang Lefevre (ed.) may be obtained as a free download from the Max Planck Institute for the History of Science at:
http://www.mpiwg-berlin.mpg.de/Preprints/P333.PDF
(2) London National Gallery, Hans Holbein 1497 – 1543. A high resolution digital image of the lute and books - necessary for study of these details of the painting - may be downloaded from :
http://commons.wikimedia.org
On the home page, search for ‘Holbein lute’. File size is about 2.6MB. It is assumed that published images of the painting do not contain distortions introduced by the reproduction processes.
Oud or Lute? - The Ambassadors Lute Seen from a Computer's Perspective.

Mahmoud Korek (1) recently undertook a preliminary study of the lute depicted in Holbein’s ‘The Ambassadors’ painting using three-dimensional imaging software.

Summary
The subject matter of the painting is enigmatic and remains open to interpretation. The results of Mahmoud’s preliminary study of the lute indicate that the instrument, as rendered by the computer in orthogonal projection, has a body profile very close to that of the Arnault de Zwolle lute geometry but with a neck length that is only about a quarter of the overall length of the instrument. This leads to three conclusions:

(a) That the painting of the lute is a composite of two or possibly three separate images carefully blended together to look convincing to an observer.

(b) That the instrument, used as a model by Holbein, was an old oud (or oud like lute) from an earlier period than the 16th C. - the image being altered by the artist to represent an ‘up to date’ six course lute of his time.

(c) That the artist used a concave mirror as an optical projection device resulting in distortions to the perspective rendering of the lute.

Experimental Procedure
The computer software employed for this study enables a true perspective view (2) of a volume to be generated through the lens of a virtual camera - the choice of lens characteristics and specifications ranging from extreme telephoto (near orthogonal) to extreme wide angle (near ‘fish eye’). The lens simulator used for the trials was a ‘Mentalray Camera shader’ (Mentalray being a rendering engine) which uses ‘real’ camera lens distortion algorithms to correctly simulate lens aberrations for a chosen lens type. The virtual lens selected for the study was a 19th C ‘double gaussian’ multi element lens.

Starting with the assumption that the soundboard geometry of Holbein’s lute was identical to that of Arnault de Zwolle’s lute, the bowl was modelled as a three-dimensional ‘wire frame’ structure. Viewed through the virtual lens, adjustments to the camera position and the proportions of the generated image in perspective view were made until - applied as an overlay - the image matched the image of the lute in the painting. From this data, it was then possible to compute and render orthogonal projections of the virtual 3D image.

Results and Discussion
The results confirm that the Arnault de Zwolle lute profile is a very close match – as can be seen in the perspective overlay (Fig 1). However, the peg box, neck and bridge, although they are a close fit, do not conform exactly to true perspective - both appearing to be rotated slightly towards the observer. The bridge in particular appears to have been painted in an almost ‘head on’ view.

The lute image - rendered in orthogonal projection, front and side elevation - is shown in Fig 3a. This reveals what may be a fundamental deviation in Holbein’s representation of the perspective. The neck of the lute is only of sufficient length to accommodate a maximum of six frets - not eight as depicted in the painting. A sketch of the Arnault de Zwolle lute, with an
appropriate length of neck, is shown in Fig 3b for comparison. Based upon this comparison, the length of the neck as rendered in the orthogonal image seems to be about 70% of what it should be.

If a string length of 59 cm can be assumed for Holbein’s lute, the proportional width of the body would be 34 cm and length 44 cm. Based upon physical considerations (peg spacing etc.), the minimum length of the peg box of a 16th C six course lute should measure about 170 mm overall, to the top edge of the nut (and equal to the depth of the bowl). Therefore, the orthogonal projection of the peg box would seem, like the neck, to be about 70% full size. Scaling up, the width of the fingerboard at the nut would be about 53 mm – a bit wide but still acceptable. This suggests that the painting of the lute may be a composite of two or three separate images – the peg box, neck (or peg box and neck combined) and bowl/sound board – each represented true perspective as well as scale. Note the junction of the fingerboard to soundboard, which overlaps the neck joint and lacks clear definition, as well as the excessively wide, sloping neck joint, curved side of the fingerboard and longitudinal curve of the neck. These may all be indications that Holbein skillfully matched smaller scale images of the peg box and neck to a larger scale image of the lute bowl and soundboard (see Figs 1 and 5).

(For information and comparison, an approximate representation of perspective foreshortening of neck and peg box relative to bowl may be seen in the photograph of a real lute. The instrument (Fig 2) is based on a Laux Maler lute which differs by having a relatively long, narrow body profile, low bridge position, with the peg box set at a slight angle to the fingerboard, not at 90 degrees. Note how closely the profile of this lute also seems to match that of Holbein’s lute from this low angle perspective viewpoint).

Further evidence of possible image adjustment by the artist may be found in the portrayal of the strings – strings that seem to curve. However, a closer examination reveals three points where the strings deviate from a straight line (by about a degree or so in each case) – suggesting stepwise adjustments to the image. The first deviation is immediately before the bridge (the strings seeming to curve up towards the bridge – Fig 4), the second between frets #7 and #8 and the third, between frets #1 and #2 (Fig 5).

Why would Holbein – superlative artist and technician that he was – choose not to accurately represent the lute in all of its true perspective proportions? The answer may be, simply, because it would not have ‘looked right’ in the overall composition of the painting – a painting that, according to David Hockney (3) may, in part, be a ‘collage’ of images each created individually with the aid of an optical projection device such as a concave mirror.

Speculating further, although the computer generated orthogonal projections, as they stand, cannot represent a six course lute with eight frets on the fingerboard, they might well represent an oud or an ‘oud like’ lute surviving from a period earlier than the early 16th C – an instrument with five frets on the finger board and fitted with four double courses. Assuming a string length of 59 cm, the soundboard width of the computer orthogonal projection would scale to 38 cm and peg box length to about 135 cm – sufficient to accommodate eight pegs. The finger board width at the nut scales to about 40 mm. – more than enough space to accommodate four double courses.

The length of the neck is only a quarter of the overall length of the instrument – relatively short even for a modern oud. However this neck length is consistent with the typical proportions of an oud described in the 14th C Persian manuscript the ‘Kanz al-tuhaf’ (4). Perhaps Holbein had an old lute of this kind to hand as his model that he painted ‘by eye’, albeit with some slight
perspective errors. Perhaps he then chose to represent the instrument as a 'more modern' six course/eight fret lute - readily done in a painting by adding extra strings, pegs and frets to the otherwise unaltered perspective profile. (Note the apparent cramped spacing of the pegs in the peg box).

The inclusion of an oud would have been consistent with other objects in the painting that have obvious Arabic origins (for example the rug and scientific instruments). Do these objects have some cultural significance relating to the French ambassadors - or are they just a reflection of the general widespread Arabic influence that shaped art and science of the Renaissance period in Europe?

A third speculation is that Holbein may have used a concave mirror as a drawing aid - the optical aberrations inherent in the projected image resulting in the image distortion evident in the painting. This theory has yet to be tested.

Notes.
(1) My appreciation and thanks to Mahmoud. As a 'fellow researcher' his interest, continuing support and encouragement, have helped enormously in my efforts to explore oud history and related development of the early lute. Fluent in English, Arabic and French, his scholarly discipline and in depth knowledge of the oud and its musical traditions (not to mention experience in computer graphics applications) have all been indispensable.

(2) True perspective meaning that objects closer to an observer appear to be larger than those that are more distant - consistent with a straight-line vanishing point geometry.

(3) 'Secret Knowledge', pp56, 57, and 100.

(4) The dimensions given in the original manuscript are suspect - possible scribal errors. A corrected geometry of the oud is proposed by Curtis Bouterse in his article 'Reconstructing the Medieval Arabic Lute: a Reconstruction of Farmer's 'Structure of the Arabic and Persian Lute', Galpin Society Journal #32, May 1979. This shows a long almond shaped body profile to the oud dictated by the relatively high bridge position. However, assuming a lower bridge position would bring the bowl profile close to that of the Arnault de Zwolle lute.
A Brief Review of Sound Hole Configuration in Early Ouds/Lutes.

A replica of the early oud/lute, discussed in Comms. 1819 and 1851, is currently under construction. As work on the sound board advanced, a decision had to be made concerning the sound hole configuration. The engraving of the oud shows two medium sized sound holes located close to the bridge, however, to date, no examples of this exact arrangement have been found in the iconography. The barring layout of the replica oud/lute has been derived in part from the Arnault de Zwolle lute geometry which has an identical sound board profile and a single large diameter sound hole. This central sound hole may have been omitted in order to simplify the engraving work and avoid visual confusion. However, as there is no pictorial evidence of an early oud or lute with two medium sizes sound holes as well as a large diameter central sound hole, this arrangement has been discounted as an historical option.

From a cursory examination of early Arabic and Persian sources and pre-Renaissance European paintings, the following would seem to be the range of options for sound hole arrangements in ouds and/or lutes (1):

a) The earliest representations of ouds - or oud like instruments - show the soundboards either without sound holes or with small pierced holes situated at the soundboard periphery. The original function of these small diameter holes may have been to vent the hermetically sealed bowl cavity in order to allow the soundboard to vibrate with a greater freedom.

b) One miniature painting (unidentified source, possibly Persian, 12th C.) shows an oud with two medium sized sound holes (as in the oud/lute engraving) but with an additional small, oval shaped sound hole placed in the upper part of the soundboard.
c) A modification of (b) may be seen in the early 15th C painting 'The Virgin and Child' by Masaccio (2) which shows two musicians playing unfretted 'oud like' lutes with plectrums. Here both instruments have a small central rosette located near the neck as well as a single large diameter sound hole situated close to the bridge (possibly a development amalgamating two medium sized sound holes into one?). The potential for damage, by a plectrum, to a rosette in this location is obvious – a problem avoided by having two smaller separated sound holes. Another example of this sound hole arrangement appears in a late 15th C. painting by Botticini although here there is no evidence of a plectrum being used (3).

d) An example of a lute with a large central rosette located close to the bridge, but without a small sound hole, can be seen in the late 15th C. painting by Cosimo Tura 'Virgin and Child Enthroned'(4). The lute player, in this case, does not appear to be using a plectrum.

e) The possibility of plectrum damage to the rosette is eliminated by positioning the sound hole further away from the bridge - an arrangement commonly found on ouds to this day. This is also the sound hole arrangement, with few exceptions, generally found on surviving lutes of the 16th and 17th C.
f) Another sound hole arrangement, still found on modern ouds, is a single large diameter sound hole together with two much smaller diameter sound holes – all located away from the area close to the bridge. The combined area of the three sound holes is generally equivalent to that of the single sound hole alternative in (e).

![Image](image1.jpg)


g) The ‘oud arbi’, a four course fretted oud now rarely to be found, has a triple sound hole arrangement – two medium sized and one small – positioned, as a group, close to the neck. Interestingly, the rosettes on these instruments are often cut into the soundboard - a feature invariably found in lutes but never in present day ouds.

![Image](image2.jpg)

Given the above alternatives, option (b) has been chosen for the oud/lute replica project. The two medium sized rosettes have been made the same relative diameter and placed in the same relative positions as the sound holes in the engraving. A smaller sound hole has been positioned between bars #5 and #6 - the location dictating its maximum diameter. Interestingly, the combined areas of the three sound holes is within 7% of that of a single large sound hole determined by the Arnault de Zwolle lute geometry. All rosettes have been ‘cut in’ to the sound board.

A full report on the completed project may be the subject of a future Comm.

Notes
(1) See also Comm. 195
(2) #3046, National Gallery, London. Masaccio 1401 – 1429.
Glue – More information from the Asiatic Bowmakers.

Further to Comm. 1836, here is a bit more information about hide and isinglass (fish) glue gleaned from the experiences of bowyers who make replicas of early Asiatic compound reflex bows. As both hide and isinglass glues were used traditionally in the construction of these weapons as well as musical instruments, there may be something useful for instrument makers to learn about these materials from the bow makers.

Although there are many extant historical artifacts and surviving early records providing information about the materials used in bow construction and their application, much still remains to be rediscovered – the last of the professional Asiatic bowyers having taken their knowledge to the grave over 70 years ago.

The compact and powerful Asian compound reflex bows of antiquity were constructed with layers of sinew, saturated and fixed to the back of the wooden core of a bow (the side facing away from the archer) with hide or isinglass glue or a combination of both. The inside face of the wooden core was lined with a thin layer of horn glued in place. Sinew puts the structure of a bow under extreme tension and the horn provides a complementary compressive stress when a bow is drawn.

Ohio based bowyer Lukas Novotny builds successful reconstructions of early Asian bows (1). After preparation and separation into long strands, the dried sinew is applied in several layers, allowing glue and sinew to thoroughly dry (and shrink) for several months between each application. The shrinkage of the sinew is used to aid in the critical process of forming the bow into an extreme reverse curve where the limbs are formed into a complete circle (like a pretzel) at the final stage of construction. The bow is left to dry in this state for at least a year.

Figure 1 shows a bow at four stages – the final stage of construction, unstrung, strung and at full draw.
Interestingly, Novotny claims that hide glue only reaches its full strength after 10 years. Perhaps this aging process of the glue may be part of the reason why musical instruments take time – often years – to fully mature and come into ‘full voice’?

Other researchers, involved in constructing replicas of early Asiatic bows, have encountered problems when using isinglass glue to fix horn laminations to the wooden core of a bow. The difficulty apparently, is that isinglass glue, although used hot at 65 C (150 F), has a high molecular weight, which prevents it being absorbed into the surface of the horn. The solution is to dilute the stronger isinglass glue with weaker but “more penetrating” hide glue. Unfortunately, no information is provided about the relative proportions of isinglass to hide glue used in these investigations.

Thomas Mace (2) recommended using hide/isinglass glue mixtures for repairing his lutes – rather than just hide glue. Perhaps this glue combination was used by luthiers of Mace’s time and earlier primarily for gluing ivory to wood (for example for making ivory/ebony inter rib purfling or for gluing ivory ribs to the purfling)?

Dick Baugh, recently carried out an investigation into why sinew is effective as a material for Asiatic bow construction when its elastic modulus, at 411,000 p.s.i., is much less than that of wood (3). His tests and measurements confirmed that sinew shrinks about 3% when dried. He concluded that it is the shrinkage of the sinew that makes the difference - supporting the wooden core of the bow to allow stretching of the core under tension by 5% (normally wood can only stretch about 1% under tension before breaking). Baugh experimented with two types of glue – hot hide glue and cold setting ‘Elmers’ carpenters glue (a PVA adhesive). Baugh found that hide glue shrinks to the same degree as the sinew when it dries whereas PVA glue does not shrink at all. He used hot hide glue to make a functional, powerful composite reflex bow whereas a bow made with the PVA adhesive was weak and totally lacking in performance.

The tendency of PVA adhesives to ‘creep’ under load is also likely part of the reason for their unsuitability for this application - the glue yielding under the extreme stress encountered both when a bow is in its unstrung state as well as when fully drawn. Hide glue or a hide glue /isinglass combinations, on the other hand, withstand this stress condition without yielding – provided a bow is not used in a hot humid environment that would cause softening of the glue and consequent loss of integrity of the bow structure. A good enough reason to choose hide glue over PVA adhesives for musical instrument construction.

Notes
(1) Reported in the article “History’s Curve” by Lee Lawrence published by Saudi Aramco World Vol. 54, #5. The full article may be downloaded from; http://www.texasarchery.org/Documents/SaudiAramcoWorld/historys_curve.htm
(2) ‘Musick’s Monument’, London, 1676
(3) “A Note on Indian Bow Making or the Secrets of Sinew Revealed”. The full article may be downloaded from; http://www.primitiveways.com/secrets_of_sinew.html
MAKING A RECORDER BLOCK

From personal experience I suspect there may be a few amateurs like me who find that making a one-piece recorder block is a difficult and time-consuming exercise. I'm sure it must be very satisfying to turn out a perfect block in half an hour; I hope to achieve that someday. But for those of us who are still honing their technique, a quick method of providing blocks for finished instruments can be very useful. I offer the following solution for anyone who has a table-mounted router and doesn't mind using a two-piece block.

For a treble recorder I start with a piece of cedar 120 mm long, nicely squared to about 25 mm. The ends are accurately marked for turning between centres and a tapered cylinder is turned over a length of 70mm to match the dimensions of the block reamer. The taper will continue for 5mm at each end to allow for error, but it's important to leave 25mm of square stock at each end. Now we're ready for the router.

A mortising gauge set to the width of the windway is used to mark across the square ends, serving as a guide for the cutter setup. The cutter will have a diameter smaller than the windway width but greater than half the width, so that when the piece is reversed for the second cut, a symmetric channel will be cut down the middle of the cylinder having the same dimension as the windway. At this point it will become obvious that the squared ends are used to bear against the router fence to keep everything perfectly aligned, and I aim for a depth of cut that will make the join line as unobtrusive as possible. Now it's time to remove the square ends to test the block for goodness of fit in the head-joint and to mark the block length accurately.

The final step involves shaping a second piece of cedar to fit snugly in the channel to form the upstand. After it has been glued in place, the upstand can be shaped to produce the final block.

At this point I should emphasise that this method works quite well for a parallel windway, but requires more finesse when dealing with tapered windways. I've tried two modifications to cope with this problem. The first is quite simple: make the channel equal in width to the narrowest dimension of the windway, then carefully form the taper by hand. The second requires some careful calculations to taper the original piece of squared cedar to match the taper of the windway. I find the former method much easier.
Supporting Claims of Kithara or Lyre Origin

In a previous Comm featuring consequences of the invention of the tuning peg, I mentioned the distinction made by Isidore of Seville around 630 AD between the cithara and the psaltery: the psaltery's sound comes out higher than where the strings were actuated, and the cithara's sound comes out lower than where the strings are actuated. These names were apparently in common use for classes of instruments, each including a variety of designs (often with individual names, some of which were mentioned by Isidore), and some sort of rationale was needed to justify distinguishing between the two classes. Isidore wrote that an 'ancient' name for the cithara was 'fidicula' and 'fidicen', which I suggested is a contribution to the later name 'fiddle'. I also suggested that a stringed instrument seen on Roman sarcophagi that conforms to Isidore's criterion for being a cithara, and often seen being played like the original Greek instrument, developed into the later fiddle, and I will call this type of cithara a 'proto fiddle'.

I now also suggest that another stringed instrument occasionally seen on Roman sarcophagi which had a bulbous back like a lute was also considered to be a type of cithara. It is possible that narratives that included descriptions of them survived till late in the millennium. Then, when the Arab lute came to Sicily and spread northwards in Italy, it was considered to be a revival of the Roman proto-lute cithara. This possibility offers a grain of historical support for the claim of Italian lute players from around 1500 that the lute was the contemporary descendent of the ancient Greek lyre. Of course, the purpose of the claim was to avoid condemnation of the lute as a Muslim instrument by the Spanish pope, as happened in the Spanish Inquisition. The historical chain of links would be Renaissance lute – medieval lute – Roman proto-lute cithara – Greek kithara – Greek lyre.

Other instruments also claimed descent from the Greek kithara or lyre. The Italian lira that flourished early in the Renaissance made this claim by its name. Ganassi claimed that the viol was just a large version of the Greek lyre, and should be called 'lirone'. The historical chain of links would be viol - lira – medieval fiddle – plucked fiddle – Roman proto-fiddle cithara - etc. The similar claim of the citole would be to come from the plucked fiddle, or directly from the Roman cithara (including suggestions of the wings of some more Greek-like versions).

The reason for these and other similar claims were obviously to establish a mystical historical legitimacy, but I am suggesting that it was not necessarily pure propaganda, though the claimants were probably unaware of any real historical justification.
On the Development of Early Music

Throughout the history of Western European music, current repertory has always included music composed in previous periods. Earlier composers were respected for the music they produced that could be successfully performed as contemporary music was. Most people felt that current music composition and performance were more advanced than in previous times, and wouldn't seriously consider performing anything in earlier styles. It was not till 19th century musicologists began to compile complete editions of revered earlier composers did questions concerning the composers original intentions and expectations surface. In that century, music by dead composers became more popular. Many soloists became famous by playing mainly compositions that were not their own compositions, and it started to be fashionable for them to respond to praise for their performances by modestly claiming that they were only the vehicle for the expression of the dead composer. Composers became more important than musicians. There was also considerable interest in all things antiquarian, including music.

In the first half of the 20th century, much pre-classical music was known, mainly vocal music and instrumental music transcribed for modern instruments. A few professional players performed on early types of instruments that were usually 'improved' versions of the early ones. Cheap recorders were made and became common in schools, usually as a first step towards playing modern wind instruments. A few viol groups formed and a few played lutes and harpsichords. Early versions of modern instruments like guitars, pianos and violins were avoided. These activities usually were isolated efforts by individuals and small groups of amateurs or semi-professionals. They provided a market for music editions prepared by musicologists, and the availability of these editions encouraged more of these activities.

The early music movement initially grew with these amateur and semi-professional instrumentists and instrument makers. Their philosophy was to carry the fashionable idea of fidelity to the intentions of the composers to the next logical step: to re-create the kinds of sounds the composers wrote for. In the 2nd half of the century, makers increasingly gathered whatever detailed information they could on original instruments. Some tried to reproduce in detail what they imagined the instruments were like when originally made. Most eschewed what they considered to be 'slavish' copying (which they were sure that the original makers didn't do) and made designs of their own in what they believed was the 'spirit' of the originals. Those creative makers whose concepts of 'spirit' included aspects that obviously were not historically accurate were soon mostly sidelined because, for the players, there was kudos associated with how authentic the equipment they used was. This attitude did not extend to instrument accessories. Players didn't worry about string types, preferring modern ones that sound similarly and break less often. So lutes used nylon instead of gut strings (gut top strings don't last at modern popular lute sizes and pitch standards) and keyboards used phosphor bronze instead of brass and modern steel instead of iron strings. Reed instrument players used reeds close to modern ones, finding copies of surviving early reeds 'unplayable'. The idea that one can learn about authentic practices by using authentic equipment was nice in theory but rarely 'realistic' in practice.

With support from funding agencies and the media, groups such as Michael Morrow's 'Musica Reservata' and especially its offspring David Muñoz's 'Early Music Group' had great success. This led to profound changes. Its growing popularity made early music commercial, with professional players and makers taking the lead. Progress in exploring authentic performance practices slowed considerably since professionalism in the modern music world requires a precision in intonation and ensemble very rarely demanded in the early days. Also, a modern badge of professionalism is to be able to play very fast cleanly. Thus there was much investment of time practicing with whatever technique one had, and this inhibited exploring alternatives. Whatever appeared to work convincingly was copied and became modern traditions. The media sold early music to the public.
as a re-creation of what one's ancestors heard, and the audiences wanted to believe this without any ifs or buts. The players who cared about historical accuracy knew that there were still many modern compromises, but they could not discuss them publicly. The use of the word 'authenticity' for historical accuracy was suppressed in what musicians wrote. There was much concern that the early music 'bubble' would burst, so there was considerable pressure not to rock the boat.

Once it became clear that professional careers can be successfully pursued in early music, professionally trained musicians of all sorts wanted to join in. Early operas were performed and baroque orchestras were formed. With early versions of modern orchestral instruments now included, they had a problem more difficult than early instruments previously involved, that of distinguishing themselves clearly from modern versions. This was accomplished by fiddles adopting the string types popular in the 19th century with gut higher strings and metal-wound lower ones, and by all adopting a different pitch standard, a semitone lower than modern. The latter choice made gut violin 1sts last longer, and eased copying of the highly successful mid-baroque French woodwinds, which were made for near this pitch. Vibrato was considerably reduced. The style of playing was the very modern one of valuing clarity, transparency, precision and sharpness, rejecting what was considered the excessive lyricism, indulgence and big sound of the Romantic period.

Now, a few decades later, there has been some further movement towards historical accuracy in the stringing of bowed instruments, with more metal-wound low strings replaced by all-gut strings, and in the stringing of keyboard instruments, with brass replacing phosphor bronze and mild steel (called 'iron') replacing piano steel (the original phosphorus iron is still not made). Otherwise, the trend has been otherwise. Worry about the possible bursting of the early music 'bubble' has diminished. A new generation of performers is secure in the early music style they have inherited, and it assumes that all problems of historical accuracy in performance practices were solved generations ago. With security, and 'authenticity' successfully replaced by 'historically informed' without objection, the pressure to try to produce what the composer might have expected has been substantially reduced, and performers have become freer from historical restraints in their interpretations. Their focus has primarily been on what musicians throughout the ages have mainly been concerned with: providing the entertainment expected by those paying for it. That involves offering variety by researching and introducing new repertoire, making new arrangements (sometimes with adding improvised parts not necessarily in historical style), and offering excitement by using tempos that often display the great speed that modern training provides, and sometimes even following the fashion of energy projection in popular music, using dance-like movements while performing.

Early music has become a highly successful component of contemporary music culture, and doesn't need not seek changes. Nevertheless, there will be the slow ones of fashion that all such cultures are subject to.

Much of my work has been devoted to studying aspects of music history that were not properly understood when early music, in its need for standardisation, made its assumptions. The modern professional music world is globalised, and standardisation is necessary because the economics requires a stylistic unity in performance with minimum rehearsal time when musicians are assembled. Musicians have to fit in with others wherever they go, using the same musical language.

The conclusions I came to rarely agreed with the assumptions of early music. Since my work did not clearly point towards greater attractiveness in the music, there has been every practical reason for the musicians to ignore them. But the professional music historians usually ignored them as well. They have liked the way early music sounded, and any scholarly conclusion that challenged that sound was suspect, and there was no interest in carefully examining them. They are content to contribute both to knowledge of music history and to the early music culture, and refuse
to contemplate circumstances where there might be some conflict between them. My contributions tend to find such conflicts, so I am sidelined. Consequently, FoMRHRI Quarterly is an excellent outlet for publishing my work. It is a good place to publish what will be mostly ignored, but might be found and understood later in a different climate, when early music is at a different stage of development, and perhaps when reasoned explanations of all of the relevant evidence are at least as important in music-history scholarship as how 'convincing' the music sounds.

It is possible that some time in the future, there will be more diversity in early music, and some groups may be interested in the different attractiveness of more historically accurate practices. For instance, the original 17th century English and French consort viols were about 20% larger than modern ones, and were usually played at pitch levels more than a tone lower than modern a=440. Appreciation of the sound of bowed thick all-gut bass strings is growing nowadays. That will surely increase with the larger viols at the lower pitches, and the thin strings will sound richer as well. That low pitch would also benefit lutes because top strings made of gut would then last, and so encourage all-gut stringing, resulting in a growing appreciation of the unique warm sound of plucked (adequately-twisted) thick gut basses.

Some viol players may be willing to try playing most notes percussively like on the harpsichord or lute (as indicated in French and English sources) instead of using the modern standard messa-di-voce style (which I liken to the sound of a harmonium). This would add considerable clarity to the rhythmic structure of the polyphony. The short scratch at the beginning of the note imitates the consonant that starts most words or syllables. The viol and the voice articulated and phrased in the same verbal way - like that of the orator, not of the later bel canto singer, which is the modern way. If they try this, they will find how useful decorating notes is in supplementing dynamics to provide the emphasis for some of the orator's words. Un-notated decoration was not just baroque bling, and avoiding it is a matter of ignorance supported by a fashion of post-modern minimalism.

Some musicians, perhaps bored with just assimilating performance style through their ears alone, may re-examine the early evidence on decoration from descriptions, and especially the examples in music with extensive indicated decoration, and they may then develop a much more sophisticated decorated style for each type and period of the music they play. They would then appreciate the slower tempi indicated by the tempo evidence, which would offer them the space in which more decorated performances can be expressed.

It is more likely that early music will evolve in more populist directions than in such more historical directions, but niche groups adopting the latter approach may prosper.
The 350th anniversary of his birth has focussed attention on Henry Purcell. This paper discusses his writings on counting common time. In John Playford *Introduction to the Skill of Musick* (London, 1694) "Corrected and Amended by Mr. Henry Purcell", p. 25, he wrote:

First, I shall speak of Common-Time, which may be reckoned three several sorts; the first and slowest of all is marked thus C: 'Tis measured by a Semibreve, which you must divide into four equal Parts, telling one, two, three, four, distinctly, putting your Hand or Foot down when you tell one, two and taking it up when you tell three, four, so you are as long down as up. Stand by a large Chamber-Clock, and beat your Hand or Foot (as I have before observed) to the slow Motions of the Pendulum, telling one, two, with your Hand down as you hear it strike, and three, four, with your Hand up; which Measure I would have you observe in this slow sort of Common Time: Also you must observe to have your Hand or Foot down at the beginning at every Bar.

The second sort of Common time is a little faster, which is known by the Mood, having a stroke drawn through it, thus Ć.

The third sort of Common Time is quickest of all, and then the Mood is retorted thus $; you may tell one, two, three, four, in a Bar almost as fast as the regular Motions of a Watch. The French Mark for this retorted Time, is a large Figure of 2.

Most early writers about tempos compared different ones in a relative way. They knew what their usual tempos were, and their readers could readily associate what they read with the tempos they heard around them. When we read their writings centuries later, we are also tempted to associate their tempos with those of our own experience. Since musical practices can change radically over the centuries, for the sake of historical accuracy, we should first check this expectation against the occasional surviving pieces of evidence concerning absolute tempos. In the above discussion, Purcell provided two such pieces of evidence: the 'slow motions of the pendulum of a large chamber clock' and the 'regular motions of a watch'. The purpose here is to determine what absolute tempos these pieces of evidence imply.

Horologists know all about the usual large chamber clocks and watches of Purcell's time. Clocks and watches of that period had verge escapements, and each oscillation of the balance wheel produced two very different sounds: one was an escapement and the other was a recoil. It really was 'tick, tock, tick, tock', not 'tick, tick, tick, tick', as more recent timepieces sound. A full oscillation of the pendulum of such a clock (swinging one way and then back again) takes the time (between either only ticks or only tocks) of 2 seconds, and a full oscillation of the balance wheel of such a watch takes 0.40 second. If the 'slow motions' of the pendulum meant holding one's hand still for each 'strike' of a full oscillation (counting a number for each swing), then in C, crotchet = MM 60. If the 'regular' motions of a watch meant counting a number for each balance-wheel oscillation, then in $, crotchet = somewhat less than MM 150. This relationship between the tempos of C and $ is about right since before Purcell, retorted time meant twice the speed of a general slow tempo indiscriminately called C or Ć.

A possible alternative interpretation is tempos twice as fast for both, with counting two numbers per swing of the pendulum, and not differentiating between ticks and tocks of the watch, counting all four numbers in less than a second. Modern expectations prefer these tempos. This interpretation is argued against by the evidence. Purcell specified 'slow motions' of the pendulum, implying that it was not 'fast' motions, as this would appear to be. Purcell specified 'regular motions' of the watch, implying that it was not non-regular motions - with 'regular' probably meaning truly repeating motions, and 'irregular' meaning counting ticks and tocks indiscriminately.
Also, counting four numbers in less than a second is rather rushed, not 'moderately' counted, as Purcell indicated in his *Lessons* (1696), where he described the three sorts of Common time, adding 'each of them has alwayes to ye length of one Semibrief in a barr, which is to be held in playing as long as you can moderately tell four, by saying one, two, three, four,...'.

Other 17th century English evidence more strongly supports the original interpretation above. When discussing how to keep common time (notated with either C or ⫸), Christopher Simpson, in *A Compendium of Practical Musick* (London, 1667), wrote 'Some speak of having recourse to the motion of a lively pulse for the measure of crotchets, or to the little minutes of a steady going watch for quavers'. The normal pulse ranges from MM 60-80, and a lively pulse would be high in that range. What 'little minutes of a ... watch' meant is not so clear, but for it to be consistent with the pulse information, it should be the same as the interpretation given here of Purcell’s ‘regular motions of a watch’, with quaver = MM 150 (crotchet = MM 75).

Further confirmation that in slow (i.e. not retorted) common time, the crotchet was in the pulse range, comes from Thomas Mace in *Musick’s Monument* (London. 1676). He suggested that an aid for keeping time would be to attach a string to the ceiling, and to tie a weight to it, almost touching the floor. To start this pendulum off, one lifts the weight to one side as high as one can reach and lets go. He made it very clear that a full oscillation of the pendulum (including swings in both directions) corresponded to a semibreve in common time. For crotchet = MM 60, the ceiling would have to be 4 metres above the floor, and for crotchet = MM 80, it would have to be 2¾ metres above the floor. The tempo couldn’t be any faster because the ceiling would be too low to start the pendulum by raising the weight as high as one can reach, as instructed. Mace described his own music room: It had an arched ceiling and was shaped in a square with sides 6 yards long. There were galleries 3 yards deep along each side, and small balconies extending beyond the galleries. With a room this big, about four metres is a very reasonable estimate of the ceiling height over the floor.

Thus the original interpretation of Purcell’s clock pendulum evidence, with counting a number with each swing, leading to crotchet = MM 60 is confirmed, and the alternative interpretation leading to crotchet = MM 120 is to be rejected.

The basic common-time tempo of crotchet = MM 60 was standard in England, and probably elsewhere (yes, including Bach), well into the 18th century, as evidenced by the statement by William Tans’ur in *A new musical grammar* of 1746 (p. 44), that a crotchet lasts for a second. Modern tempos tend to be at least twice as fast. Performance at original tempos can only be acceptable to modern ears if early musicians developing a more sophisticated approach to original embellishment practices than is currently evident.
A basic theory about string twist

Let us first consider a string made of a number of fibres that start out parallel and are then twisted together. The list of parameters in this analysis is as follows:

- \( R \) is half the diameter of the twisted string
- \( R_0 \) is half the diameter of the original untwisted string
- \( r \) is the radius from the string axis to a spiralling fibre
- \( \phi_r \) is the angle the fibre makes with the string axis at radius \( r \)
- \( \phi_0 \) is the average fibre angle
- \( \phi_R \) is the fibre angle at the string surface
- \( L \) is the length of the string
- \( L_0 \) is the length of the original untwisted string
- \( n \) is the number of turns of twist in the string
- \( E \) is the elastic modulus (or more appropriately, the stiffness modulus) of the string
- \( E_0 \) is the elastic modulus of the original untwisted string

This exercise is to evaluate the others in terms of the independent parameters \( R_0, L_0, n \) and \( E_0 \). The number of gut fibres in the string is proportional to \( R_0^2 \), and the proportionality constant depends on the sheep breed, which part of the sheep's gut has been used, and how the gut has been prepared. From Mersenne's information, if the number of guts is called \( m \), \( R_0 = 0.25 \sqrt{m} \) in mm.

The angle the fibre makes with the string axis (\( \phi_r \)) can be best visualised by projecting the fibre spiral onto a plane parallel to the string axis. Then \( \phi_r \) is the angle between the axis and the projected spiral where they cross. If we consider the cylinder that the spiral is in, and conceptually split it along a line parallel to the string axis and flatten it into a plane, the spiral becomes a straight line going diagonally from the bottom of the opened cylinder to its top for one turn, and then repeating for the next turn. The fibre spiral is the diagonal of a right triangle of which the two other sides are \( 2\pi r \) and \( L/n \). Then \( \tan \phi_r = 2\pi r n/L \). On the string surface, \( \tan \phi_R = 2\pi R n/L \).

The fibres spiralling near the surface of the string have a longer path than those near the centre. Before twisting, their lengths were the same. When tension is put on the string while the fibres are still wet and slippery, the tension in the fibres near the surface, being greater than in the fibres near the centre, would make them migrate towards the centre, pushing outwards those fibres already there, tending to equalise the fibre tensions. The model here assumes that along the length of the string, individual fibres wander amongst the available radii from the string axis.

There must be an average \( \phi_0 \) at a particular \( r \), that has the same contraction with twisting as the whole string, so \( \cos \phi_0 = L/L_0 \). We assume that the density and volume of the string is unchanged during twisting, so \( \pi R^2 L = \pi R_0^2 L_0 \). Then \( R/L = (R_0/L_0)(\cos \phi_0)^{-3/2} \).

To do the average to get \( \cos \phi_0 \), we multiply \( \cos \phi_0 \) by \( 2\pi dr \), integrate from \( r = 0 \) to \( R \), and divide by \( \pi R^2 \). Before integration, we make the substitutions \( \cos \phi = 1/\sqrt{1+\tan^2 \phi} \) and \( \tan \phi = 2\pi n r / L \). The result of the integration is \( \cos \phi_0 = (2/\pi)(\tan^2 \phi_R)\sqrt{(1+\tan^2 \phi_0)-1} \). We can replace \( \tan \phi_R = 2\pi n L / R \) by \( 2\pi n (R_0/L_0)(\cos \phi_0)^{-3/2} \), and solve for \( \cos \phi_0 \). The result is \( \cos \phi_0 = (1/2)\sqrt{1+\sqrt{1-4\pi^2 n R_0 L_0}} \).

As twist \( n \) increases, the average twist angle \( \phi_0 \) increases, and \( \cos \phi_0 \) decreases. At maximum twist, \( \cos \phi_0 \) is at a minimum. This happens when \( 2\pi n R_0 L_0 = 1 \), resulting in \( \cos \phi_0 = 1/2 \). Then the maximum twist angle \( \phi_0 = 60^\circ \), and the amount of twist is limited by \( n R_0 L_0 = 1/2\pi = 0.159 \). From the result of the integration, we can calculate that at maximum twist, \( \tan^2 \phi_R = 8 \), so the fibre twist angle seen on the surface, \( \phi_R = 70.5^\circ \).
The elastic modulus is the ratio of stress to strain. The stress is the tension \( T \) divided by the cross-sectional area \( \pi R^2 \) and the strain is the increase in length resulting from the tension \( \Delta L \) divided by the unstretched length \( L \). Thus \( E = \frac{T/\pi R^2}{\Delta L/L} \). When the tension \( T \) stretches the string \( \Delta L \), the fibres (of length \( L_0 \)) stretch \( \Delta L(L_0/L) \) at a tension of \( T(L_0/L) \). This is equivalent to the untwisted string at that tension where \( \Delta L_0 = \Delta L(L_0/L) \) in the equation \( E_0 = \frac{T(L_0/L)/\pi R_0^2}{\Delta L_0/L_0} \). Then \( E_0 = \frac{T(L_0/L)/\pi R_0^2}{\Delta L_0/L_0} \). We can now calculate the ratio \( E/E_0 = \frac{L/L_0}{\pi R_0^2/R_0^2} = \cos^2 \phi_v \). The tensile strength is the maximum stress the string can take, which is the maximum tension the fibres can take (assumed independent of twist) multiplied by \( \cos \phi_v \) (the component in the direction of the string axis) divided by the cross-sectional area of the string. This also varies with twist according to \( \cos^2 \phi_v \).

In practice, the limit to the amount of twist is never reached. As one approaches it with wet gut, the resistance to twisting increases and one has to increase the tension to keep the string straight and not bending into a corkscrew shape. The increased tension lowers the twist angle. A contributing factor here is the component of the fibre tension perpendicular to the string axis, which compresses the fibres within each spiral. This increases the friction between fibres and inhibits the slipping readjustments needed with increased twist to equalise the fibre tensions and to affect the rapid increase in thickness. The increased tension can be released after the string is dried, when the fibres are locked into their positions. In our experience with gut, the effective maximum twist is when \( nR_0/L_0 \) is about 0.14, and in typical commercial production of high-twist strings, it is about 0.12.

Following are calculated graphs showing how the average twist angle \( \phi_v \), surface twist angle \( \phi_s \), relative thickness \( R/R_0 \) and relative stiffness \( E/E_0 \) and strength vary with the amount of twist \( nR_0/L_0 \).
Rope construction: catlins

Ropes are made by twisting a small number of already twisted strands together. That number is typically not greater than 4 or 5, since with more strands, they tend to act like the fibers in the simple twisted string discussed above, alternating between being on the surface and being near the centre, leading to an undesirably uneven surface. The rope twist adds to the strand twist if they are in the same direction, and subtracts from the strand twist if they are in opposite directions.

We shall use the same symbols for parameters analogous to the simple twisted string, but in a different font. So \( n \) is the number of turns of rope twist, \( L_0 \) is the strand length, \( L \) is the rope length, \( R \) is half the average or equivalent rope diameter and \( R_0 \) is half the equivalent untwisted rope diameter. If we call the number of strands \( p \) and \( R_1 \) half the diameter of each strand before the rope twist, then \( R_0 = R_1 \sqrt{p} \). Because there are spaces between strands, there is an increase in volume, so \( \pi R^2 L = k \pi R_0^2 L_0 \), where \( k \) is a correction factor (in our experience, it is about 1.2).

A simplifying assumption is made here: that we conceptually replace the fibre structure in each strand by elements that spiral around the rope axis as the strand axis does, and which have the mechanical properties that the strand does. This assumption reduces the solution of this problem essentially the same as that of the twisted string above. So each element has a radius \( r \) from the rope axis at an angle \( \phi \) from it, and there is an average \( \cos \phi \) so that \( \cos \phi = L/L_0 = k(R_0/R)^2 \). The same substitutions and integration as before lead to \( \cos \phi = (1/2) [1 + \sqrt{1-k(2\pi n R_0/L_0)^2}] \). Then at maximum twist \( n R_0/L_0 = 1/(2\pi k) \) and \( \cos \phi = 0.5 \), so \( \phi = 60^\circ \). At any twist, the rope bump boundaries show the angle \( \phi \) directly.

As above with the twisted string, \( E/E_0 = (L/L_0)(R_0/R)^2 \). Then \( E/E_0 = \cos^2 \phi \sqrt{k} \). Though the roping of strings to make heavier strings is known from Roman times, in the Renaissance, they were used to expand the open-string range of instruments by lowering the pitch of the lowest roped string to have the same just-tolerable inharmonicity in the sound as the previously-used lowest high-twist string. The inharmonicity parameter is proportional to the elastic modulus divided by density and to the square of the ratio of the diameter and the vibrating string length. At unchanged inharmonicity on an instrument with constant vibrating length, \( E \) multiplied by the tension divided by the product of the square of the density and the fourth power of the frequency is constant. To produce the drop of a fourth in the lowest pitch in the Renaissance, one would need to twist approximately to \( n R_0/L_0 = 0.13 \) and halve the tension. This lower tension on the lowest string could explain why they appear thinner than they would be at equal tension (as we would expect from Mersenne) in the surviving illustrations.

Following are calculated graphs showing how the rope twist angle \( \phi \) and the relative stiffness \( E/E_0 \) vary with the amount of twist \( n R_0/L_0 \) when \( k = 1.2 \).
The Young’s modulus made easy

1 Preamble.
The Young’s modulus is a constant which describes the flexibility of a material. It is well known by string instrument makers as the main factor contributing to string inharmonicity. Another less known factor is the longitudinal string vibration frequency which plays a role in the sound colour and also directly depends on the Young’s modulus. Fortunately, the longitudinal modes also provide us with a yet unpublished, cheap, non-invasive method to measure the Young’s modulus of an existing string in an instrument. The aim of this paper is to describe how to do this measurement, and how to use the result to recognise the material of the string and calculate the string’s inharmonicity.

2 Introduction.
Let us begin with an experiment. With a little rosin at a fingertip (or on a glove if required), gently rub a string lengthwise – on a pianoforte, clavichord or harpsichord it is easiest on medium or bass strings. Of course, the corresponding damper must be raised during the operation. The string will vibrate, usually producing a high pitched, fluted sound; this is the fundamental longitudinal mode.

Unlike with the usual (transverse) vibration mode, the frequency of the longitudinal mode does not depend on string tension. If in doubt, have a try and slightly detune the string; the longitudinal sound will remain unchanged.

The classical formula giving the fundamental transverse vibration frequency of a string is

\[ F_t = \frac{1}{2L}\sqrt{\frac{T}{\mu}} \]

with
- \( F_t \) frequency,
- \( L \) speaking length,
- \( T \) string tension,
- \( \mu \) mass per unit length.

Similarly, the fundamental longitudinal vibration frequency \( F_l \) is given by:

\[ F_l = \frac{1}{2L}\sqrt{\frac{E}{\rho}} \]

with
- \( \rho \) material density,
- \( E \) Young’s modulus.

which confirms the longitudinal frequency does not depend on the string tension.

3 Measuring the Young’s modulus without expensive tools.
The formula above may be written:

\[ E = 4\rho L^2 F_l^2 \]

and can be directly used to measure in-situ the Young’s modulus of an existing string.
I tried this on the centre C (c'/C4) of my 1914 Erard grand, which still retains its original strings. Its speaking length is 680mm. The rosin test gives a note three octaves plus one sixth above the normal (transverse) c’ of this string, i.e. a”'/A7. An easy calculation shows this

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corresponds to a frequency of 3520 Hz. The strings visually appear to be made from iron or steel, with a density around 7770 kg/m$^3$. Following the preceding formula, the Young’s modulus of this string is therefore

$$E = 4 \times 7770 \times 0.68^2 \times 3520^2 = 1.78 \times 10^{11} \approx 180 \text{ GPa}$$

which is perfectly typical of iron rather than steel. More generally, common values of the Young’s modulus are around:

- 300 GPa for steel
- 200 GPa for iron
- 120 GPa for brass
- 80 GPa for red copper

As we can see here, relatively recent pianofortes, even overstrung and fitted with a cast frame like this one, often carry iron strings.

In practice this method gives the Young’s modulus with an accuracy around 10%, which is sufficient in most cases. The main difficulty is not to get the wrong octave, which would anyway lead to aberrant values. Luckily enough, the Young’s modulus is not very much affected by wire drawing.$^2$

### 4 Inharmonicity.

Inharmonicity refers to the shift of the partials relative to their theoretical values as multiples of the fundamental frequency. Inharmonicity is driven by the basic inharmonicity factor, which is for a plain (unwound) string:

$$B = \pi^4 \frac{E d^4}{64 T L^2}$$

where

- $E$ is the Young’s modulus (only depending on the material);
- $d$ is the string diameter;
- $T$ is the tension;
- $L$ is the speaking length.

The actual value of each partial is:

$$f_n = n F(1 + B n^2)^{1/2}$$

On an ideal, perfectly flexible string, $B = 0$ and the partials are the exact multiples of the fundamental frequency. On real strings, the material’s stiffness tends to stretch the intervals between partials, in particular the octaves: rather than having $f_2/f_1 = 2$, we have

$$f_2/f_1 = 2 F(1 + 4B)^{1/2}/F(1 + B)^{1/2} = 2(1 + 1.5B)$$

which means the second partial is slightly more than one octave above the fundamental. On a harpsichord or clavichord, inharmonicity is only significant in the bass and is very low in the medium and treble anyway. On most pianofortes inharmonicity is higher but similar and only significant in the bass; while most 20th Century pianos also have noticeable inharmonicity in the two treble octaves, inharmonicity is still very low in the middle register and a change in the Young’s modulus would not modify it significantly. In all these cases, inharmonicity is not able to account for the proven differences in sound quality between different string makes throughout the instrument’s compass. Longitudinal vibration is one of the factors which probably play a role here.

$^2$ Goodway (Martha) and Jay Scott Odell (eds.), *The metallurgy of 17th and 18th century music wire*, in *The Historical Harpsichord*, volume two, Pendragon Press 1987.
5 Sound colour, longitudinal modes and the Young’s modulus.

On a stringed keyboard instrument, the longitudinal modes cannot be neglected:

- On a piano, the hammer flanges are never in the strings’ plane. This means that even if a hammer head is perpendicular to the string it is hitting, it will not hit the string perpendicularly but obliquely, which sets the longitudinal mode into vibration.
- On a harpsichord, as the jack motion is normally vertical, there is no initial excitation to the longitudinal modes. However, as on any stringed instrument, there is a coupling between the transverse and longitudinal modes: the response of the bridge to a vertical excitation is not vertical but oblique, depending on the soundboard and bridge geometry; moreover, the string’s tension oscillates with twice the frequency of the transversal vibration, which again excites longitudinal vibration modes.

All of the above, along with the neighbouring strings and ‘aliquot segments’, contributes to the colouring of sound through what is called the formants.

When we are speaking, our vocal cords produce a vibration similar to singing, the fundamental frequency of which is called the pitch. The shape of the mouth and the tongue’s position allow to modulate the relative power of the different parts of the spectrum and favour some parts of the spectrum, called the formants. The positions of formants define which vowel is being pronounced, independently of the pitch. Thus, for example the vowels E and O are characterised by different positions of the formants; if the same vowel is sung and the pitch is changed, the formants will remain the same and the peaks of the spectrum will move inside the formants which will be acting as envelopes. A man and a woman producing the same vowel but probably at different pitches, will use the same formants with the same absolute positions. On a spectrogram, a vowel is not characterised by its pitch or its balance of harmonics, but by its formants, i.e. the envelope which encloses these harmonics. Singing a gamut on a given vowel will result in having the spectrum moving but remaining inside this envelope.

On the other hand, when using an old fashioned analogue tape recorder, changing the tape speed moves all the frequencies the same way and the absolute position of formants will then be altered: the sound O may become E and the speech will soon become unintelligible, not because it is spoken fast but because the formants are changed.

In a stringed instrument, the longitudinal modes as resonators participate the same way to the production of formants which give the sound its colour. Our auditive system is built to recognise the absolute, not relative position of the formants (whereas the spectrum of a sound refers to the positions of partials relative to the fundamental) as this is the core of our ability to recognise speech – and be able to communicate even with the opposite sex. The characteristic colour of a stringed instrument is defined by the shape of these formants which in turn depends on the strings’ Young’s modulus.

6 Conclusion

In this paper, I showed the role of the Young’s modulus should not be restricted to its influence over inharmonicity; just as importantly, it is a fundamental factor in sound colour which should be carefully taken into account when faithfully restoring an instrument. This paper describes an easy technique to measure the Young’s modulus in situ and thus give an interesting piece of information about the acoustical properties of the material of an existing string, useful when choosing replacement strings.