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FELLOWSHIP OF MAKERS AND RESEARCHERS OF HISTORICAL INSTRUMENTS
Honorary Secretary:
Lewis Jones, London Guildhall University, 41-71 Commercial Road, London E1 1LA, U.K.
Delays in Publication - an Apology: David and I would like to apologise for the lateness of this and the previous issue. The October 2000 and January 2001 quarterlies were delayed in the first instance by a lack of comms. received by the due dates. Had we published the October issue in that month it would have been barely thicker than the first ever FoMRHI Quarterly, which amounted to four pages, so we took time to write some things and to solicit and await others. We now see that this was a grave error. Probably as a result, the lack of new material spiralled in the first half of the year, but the situation is not irreparable and material is now in hand or promised so as to allow the last of the 2001 issues to appear before the end of the year. From January 2002 we will adhere to our published deadlines, even if doing so means that an issue is occasionally very thin indeed. It is heartening now to see that this quarterly is thicker than the previous three, and that the October 2001 one, which will follow only a week or so after this, promises to be more substantial still. We would like especially to apologise to those who submitted Comms for the July issue in or soon after July, who have to wait several months for their work to emerge.

In the past Jeremy has occasionally included news of events even if there was a risk that it might reach members too late. In a similar spirit I have retained here a couple of announcements of events that, at the time of finishing this, have already taken place. In the circumstances this seems preferable to withholding information about events about which you might in any case have wished to know and with whose organisers you might like to make contact.

FoMRHI Personnel: That the transition from Eph and Jeremy to David and Lewis has been has been more disrupted than any of us would have liked has been compounded by the retirement, in close succession, of our treasurer and printer, but arrangements are now in place for smooth operation in the coming year. Partly as a consequence of these changes, David and I are working towards a new division of tasks between us, on which I will report more fully in the next Bulletin. In due course this may lead to our more formally proposing changes to our titles as officers, but in the meantime, please address both news and queries for the Bulletin and Comms. for the Quarterly to me.

Acting FoMRHI Treasurer: Barbara Stanley's retirement as Treasurer was announced in the April Bulletin. For the time being David Armitage will act as Treasurer, and will take care of the renewal of subscriptions for 2002, details of which will be announced in the October issue. In recent months, as part of his role as Editor (responsible also for distribution), David has done a terrific job in modernising and refining the membership database so as to record subscriptions received directly alongside the list from which address labels for the distribution of the Quarterly are printed. Thus the circulation list will respond immediately to new subscription information, without the need for updates to be passed between Treasurer, Secretary and Editor-cum-mailer.

Printing the FoMRHI Quarterly: Mark Ellis, who has printed the Quarterly for several years past, has retired from the trade. A teacher, Mark became involved in FoMRHI as a result of his own instrument-making activities, later taking on the role of printer. We would like to thank him for all he has done for us and, not least, for his having printed the Quarterly on generously favourable terms. We have made an arrangement for our printing to be done by the print room of London Guildhall University, who promise a five-day service for all except the October issue, when their workload may be particularly heavy at the start of the academic year. This has the advantage of avoiding the delay and risk of having copies sent in bulk by parcel post from Huddersfield to London. Their equipment is
such that we may be able to reproduce photographs to a rather better standard than has been possible hitherto, even on the ordinary paper we are used to.

**Titles of FoMRHI Comms:** FoMRHI has something of a tradition of brief and obscure titles which, however meaningful or amusing they are when they appear, can be infuriatingly unhelpful when one wants to trace something of importance later. Without wishing to be unduly formal or pompous, we would like all titles in future to convey the subject of the comm. Titles such as 'The Big Ones' or 'More on Comm...' allow their subject to sink without trace, and are almost impossible to index, let alone to find later, once indexed. The first example, we suggest, should at least have a noun indicating what it is that is big. In the case of responses to a recent comm., both the subject of the original and the act of its being responded to are important. Eph Segerman's title to Comm. 1767, 'Response to Comm. 1744: Strings of Silk and other Textiles', is a model we could accept as the norm. The original title is quoted in full and the relationship of the new comm. to the published one is stated at the outset. If the new comm. shifts the emphasis or concentrates on a single aspect of that which occasioned it, it may be better to give it a title of its own and then to note the connection between the two: 'The Technique of Twisting Silk Strings: further to Comm. 1744' is an imaginary example, and Jon Swayne's Comm. 1724, 'Pitch of electrical appliances - comments on Comm. 1706', is a real one. It would be helpful if this convention could extend to authors adding to their own work: for example, Comm. 1754, 'More on the Violino Piffaro' is clear about its subject, but for the thread connecting it to Comm. 1603 one has to refer to the text. Our inclination, if we receive good comms with obscure titles, is to intervene (amending the title so as better to serve present and future readers) rather than delaying publication to correspond with the author - but we would prefer not to feel we have to.

**FoMRHI in Directories:** FoMRHI's entries in these directories have been updated: The Strad Directory; the Aslib Directory of Information Sources in the United Kingdom (12th edition); the International Who's Who in Music and Musicians' Directory; and the Directory of British Associations published by CBD Research Ltd. As I mentioned a couple of bulletins ago, if members know of similar listings in which we might appear to advantage, I would very much welcome details.

**Dictionary of Violin Makers:** The three-volume Universal Dictionary of Violin Makers by René Vannes and Claude Lebet, published by Les Amis de la Musique in Belgium, is being revised. The compilers invite from practising makers information about their work, where they studied, the master with whom they learned violin making, prizes won, the characteristics of their work, the number of assistants they have, and their address. They would also welcome photos, labels and iron marks, to be sent by post for reasons of quality). Submissions should be sent to: Les Amis de la musique, Avenue Reine Astrid, 73, 4900 Spa-Belgique. Phone: 0032 87 77 09 62; Fax: 0032 87 77 18 34; email: musique@pi.be

**Florence Instrument Collection Opening:** From May 28th the Musical Instrument Collection of the Conservatorio Luigi Cherubini in Florence has been open to the public in a new area of the Galleria dell'Accademia. Fifty instruments from the Medici and Lorena collections are on display. These include the tenor viola and cello built by Antonio Stradivari for Ferdinando de' Medici (1690), a Stradivari violin (1716) and a cello by Nicolò Amati (ca. 1640), an ebony harpsichord and the recently rediscovered oval spinet (1690), both by Bartolomeo Cristofori. With the aid of a multimedia system, instruments and paintings from the Medici and Lorena collections will be displayed so as to reconstruct the cultural and musical ambience of the Tuscan court of the seventeenth to nineteenth centuries. A five month exhibition (May 28th - November 11th) entitled 'Music at the Granducal Court' also includes instruments on loan from the MusikinstrumentenMuseum of Leipzig University, the Library of Congress, Washington, the Museo Nazionale degli Strumenti Musicali, Rome, and the Museo Stradivariano, Cremona. Information is available from Galleria dell'Accademia, Museo degli Strumenti Musicali, via Ricabolu 60, 1 - 50122 Florence, Italy; tel./fax: +39.055.2388609; email: GalleriaAccademia.CollezioneCherubini@sbas.firenze.it.
A new catalogue of the collection and guide to the exhibition have been published to coincide with the opening. *La Musica e i suoi Strumenti, Catalogo della Collezione Granducale del Conservatorio Cherubini* (in Italian only), a cura di Franca Falletti, Renato Meucci and Gabriele Rossi-Rognoni (264 pp., about 270 black and white and 70 color pictures), with essays by Franca Falletti, Marco Chiarini, Francesca Bascialli, Flavia and Giovanna Sparapani, Marco di Pasquale and Giuliana Montanari, Renato Meucci, Luciano Marchetti and files on the instruments by Claudio Arefzo, Carlo Chiesa, Charles Beare, Paolo Coriani, Tiziano Rizzi, Gabriele Rossi-Rognoni, Kerstin Schwarz, Francesco Carreras, Alessandro Onerati, Renato Meucci, ISBN 88-09-02184-3. Price 60.000 Lire / 30.98 Euro.
The guide to the exhibition is *La musica alla corte dei Granduchi / Music at the Grand-ducal Court* (in Italian and English), a cura di Gabriele Rossi-Rognoni (139 pages, about 110 color pictures of all the instruments and pictures on display), ISBN 88-09-02185-1. Price 24.000 Lire /12.39 Euro.

**Reed Organ Convention in Saltaire:** FoMRHI but rarely ventures into the nineteenth century, let alone the early twentieth, so it is a pleasure to draw attention to an historical instrument event that does. There will be a meeting of reed organ enthusiasts on Saturday & Sunday 6th & 7th October in the Victoria Hall, Saltaire. The organisers are Phil and Pam Fluke, Curator and owner of the Harmonium Museum in Saltaire. The Saturday starts with Coffee & Registration at 10.00am. The weekend includes recitals including duos from Johannes Michel & Ernst Breidenbach, solo harmonium from Joris Verdin, Maarten Stolk playing a very old Alexandre instrument, and salon music with the London Salon Ensemble. There will be discussions, displays, opportunities for sharing experiences, discussion of ideas for restoration, and after dinner entertainment on the Saturday. There will also be displays of suitable music and of photographs of instruments, with an emphasis on approaches to restoration, and a sale of items related to reed organs, including parts. It sounds as though, within reason, any free reed instrument that can be conveyed to Saltaire is welcome for the weekend. Food is included in the fee of £70 per person. For more information contact: Pam and Phil Fluke, 6 Albert Terrace, Saltaire, Shipley, W. Yorks BD18 4PS, Telephone: 01274 585601; email: phil@harmoniumservice.demon.co

**Musikinstrumenten-Museum Leipzig:** The museum building is being reconstructed so, for the next four years, the museum has new addresses and telephone numbers, as follows:

Exhibition: Thomaskirchhof 20; Offices, Library, Conservation Department and postal address: Täubchenweg 26, D - 04317 Leipzig; Tel: +39 341 687079 0; Fax: +39 341 68707922; email: music.museum@uni-leipzig.de

**Medieval and Renaissance Music Conference, 2002:** The Medieval and Renaissance Music Conference, 2002 will be held at the University of Bristol between Thursday 18 and Sunday 21 July 2002. Proposals for papers of 20 minutes' duration are invited on all topics pertaining to medieval and renaissance music. The conference will host sessions relating to the following themes: The Trouveres; The Works of Guillaume de Machaut; and Archival Research. The emphasis of the conference is distinctly *musicological*, and it would do no harm for contributions to be offered which acknowledge the possible place of instruments in these or other aspects of the study of medieval and Renaissance music. Abstracts of no more than 300 words should be submitted by 1 January, 2002, either electronically, in Rich Text Format (RTF) to liz.leach@bris.ac.uk, or sent to Dr. Elizabeth Eva Leach, Department of Music, Victoria Rooms, Queen's Road, Clifton, Bristol, BS8 1SA, UK, before 1 January 2002. Details will appear in due course on the conference web site, which may be accessed via the Bristol University music department's home page, www.bris.ac.uk/depts/music/index.html

** Dates for the January Quarterly:** As the normal date for the October Quarterly has passed at time of printing this issue, the deadlines for January will be those announced in the October 2000 Bulletin as normal: the end of the first week of the month for items for inclusion in the Bulletin, and the end of the second week for Comms.
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Charles Stroom

Bouwerskontakt Bouwbrief 100, My Summary

Because of other things ongoing (like setting up a new PC), I will have to limit myself somewhat. Bouwbrief 100(!) starts with a short editorial, commemorating how it all started with the first Bouwbrieven in 1974, written by Toon Moonen, still an active member of both the Bouwerskontakt and of FoMRHI.

The first article is by Gerrit Menkveld and describes in great detail, including many ("50) dimensioned drawings, the construction of a chromatic metallophone ("Chromatische metallofoon"). He has written earlier articles on this subject (Bouwbriefen 77 and 78) and in the present article Menkveld adds his experience in building a number of metallophones since then. He uses aluminium for the bars (horizontally mounted as the xylophones) and includes detailed dimensions for all of them.

In a 3-page article, Francesco Leicher describes the methods to tie the frets on a baroque guitar. Material, knots and further advices are described. As this article is a "part 1", I suppose there is more to come. ("Het aanbrengen van fretten").

4.5 pages are for an article by Leo Schenkelaars, in which he describes how to make the motor and blower for an organ wind chest ("Het bouwen van een windmotor met een zelfgemaakte waaier"). The emphasis is actually on the making of the blower construction (the "waaier"). The article includes all the material used and a description of the utility tools he has made. Also this is a "part 1".

A short divertimento by Wim Rensink on the etymological meanings of the Dutch words "stapel" (of a violin) and "stapelgek" (in English: the "sound post" and literally "mad as a sound post").

Another organ article is by John Boersma ("Van Portatief naar Tafelpositief") and this is a summary of a larger German book Bau einer Kleinsorgel mit einem Register", by the same author. The organ is aimed for those who find the Renaissance portative organ too limited.

Two books are reviewed, edited by the "Topboek Company" (which I suppose is the same company as the "Tipboek Company in my summary of Bb 97). One covers the piano (upright and grand), the other the flute. Each costs about 8 euro.

Wim Krijger has written and edited the booklet (70 p.) "Klank uit hout en metaal" ("sound from wood and metal"). The book contains a large number of musical instruments for small children, with instructions and drawings how to build them. It can be ordered from the author for, again, about 8 euro (or on 4 floppies for about half that price).

Not a review, but a congratulation to Dr Jan Bouterse, who received a PhD from the University of Utrecht for his dissertation "Nederlandse houtblaasmuizen en hun bouwers 1660-1760" ("Dutch woodwind instruments and its builders 1660-1760"). His dissertation is available on CDROM (from the Huismuziek, for about 33 euro), but Jan informed me in a private email that an English translation in printed book form will become available.

Bouwbrief 100 closes with reports from 4 different active working groups (guitar, organ, strings, stringed keyboards(new)) and an interesting article by Ed van Weerd, who has been collecting the inscriptions on historical keyboards and gives an overview of what he has found so far.

Bouwerskontakt Bouwbrief 101, My next Summary

Indeed, the "Topboek" in Bb 100 should read as the "Tipboek", with apologies from the Bouwbrief editors.

Active writer (and builder) Gerrit Menkveld describes the history and secrets of the "wind harp" or Aeolian harp. Based upon an earlier article in Bb 85 (by Mark Lester), Menkveld has started investigations, not only in history, but also in construction. Aeolian harps are in the Hamburg Museum.
and construction drawings exist made by Georg Krieger. These were the basis for Menkveld and the article contains his results and drawings.

John Boersma describes an organ register (Prestant), and how to apply such register in a chamber organ. (If any reader knows of a translation of all these musical terms English ↔ Dutch, I would be grateful; many terms I don’t know even the exact meaning and, as often can be found in the terms of a software programme: I cannot be held responsible for any mistake in my interpretation of the Bb article:-) But, seriously, Boersma’s article is well written with detailed information and anyone interested in this subject, or any article, should read the original articles in the Bb.

A small gadget is described by Cees Steeg, to make the window opening in wooden organ pipes.

Koen Vermey has written an extensive book about the clavichords made by Christiaan Gottlob Hubert ("The Hubert Clavichord Data Book"), 280 pp., the result of 15 years of study. To my pleasure, one of the drawings of the book (a clavichord layout with terminology of all parts, in English, as the book is) is copied in the Bouwbrief and that should make my life easier in future. All surviving 18 clavichords have been investigated and the reviewer considers it a unique and splendid collection of clavichord data. The book can be bought from the author (100 euro), email kv@cipress.nl.

Another “Tipboek” has appeared on the market, the "Tipboek Drums".

The Bb closes with again reports from various working groups. “Toets and Snaar” (key & string) announced a study day; the organ working group reported on the open day (17 March), where a small positive organ (see Bb 100) and a box organ were demonstrated, as well as Schenkelaar’s wind chest motor (also in Bb 100). The “Strings” have had their meeting on 3 March: they discussed (again?) Chladni patterns and Hutchinson.

And apart from a small announcement of the availability of an index aka fomrhi’s and made by the same person, these were the main topics of Bb 101.
As the sub-title suggests, this is a wide-ranging survey of historic trumpets and trombones. Some of the articles are in English though rather more are in German. Some are very technical, especially those on acoustic modelling, and some of these seem to me to be misguided, especially those which are working to improve the instrument’s intonation. Leaving aside the problem that improving one note by altering bore geometry may often be disastrous for another, is there in practice a fixed pitch for any note? Admittedly my professional experience is as a timpanist and as a conductor, but I did play horn, both valve and hand, and even some natural trumpet, in many student and amateur orchestras and ensembles. Certainly as a conductor one has often to persuade players that B♭ is quite a long way from C and F♭ from E. Surely the only note with a fixed pitch is the A to which one tunes (leaving aside the Beecham-Goossens cracks) — all notes thereafter are liable to be bent one way or the other to fit their context, more when one is accompanying a piano (or vice versa since the piano cannot accompany any other instrument in this respect — it is always the master) than otherwise. The ‘better’ in tune one makes the instrument, the more difficult it may become to play in tune with everyone else.

One of these articles deals with a fascinating computer-driven technique for measuring resonances, intonation, etc.

Another compares the acoustic behaviour of a key-trumpet with a valve instrument. This, as always, was done by attaching a microphone to the thing, pushing noises into it, as used to be done through a hosepipe, and seeing how it responds. As one would expect, the sound spectrum suffers when holes are opened and, as another article says, ‘the key trumpet is difficult to play’. Equally, however, and this is what this type of analysis can never show, a good player can compensate for the open holes to a remarkable degree, as many of us have heard with Crispian Steele-Perkins. The same is true for both key bugle and ophicleide. All three sound far better in skilled hands than acoustic tests say that they should. All a bit like the bumblebee: nobody yet knows how it manages to fly when all aerodynamic theory says it shouldn’t, but it does.

There are several articles on brass-instrument making, including one by Bob Barclay on trumpet-making workshops, with the technology used in Nuremberg in the Baroque (for which see his admirable book, The Art of the Trumpet-Maker). Another by Heinrich Thein describes their manufacture and repair of brass instruments with historic processes and materials. These follow on from one by Richard Seraphinoff on the question of compromise versus authenticity when playing brass — ie holes or not. As is appropriate for someone of that name, he is on the side of the angels and believes that more and more players will try to do the job properly, but, as he says, people do have to earn a living, and if the conductors, recording engineers, and audience all insist on a seamlessly perfect performance, it’s not surprising that some people do compromise. As some players, including Crispian, have said to me, they’re willing to be brave and take a risk but they’re often not allowed to.

There are several articles on specific instruments or collections. One of particular interest by Sabine Klaus is on instruments in the Historischen Museum, Basel by makers of the Hirsbrunner family. Some of them are fairly conventional natural instruments, though one alto trombone has a backward-facing bell, but others from the 1820s and 30s have some very curious valve systems, some double-piston as in Vienna and Belgium, though with their own characteristic levers, and others a variant of the
Stölzel like no other (though with slight similarity to Samson's later finger-slides). Thirteen generations of the family are traced, from before 1600 to the present day, though the collection does not include instruments by all of them—those catalogued here are all nineteenth or early twentieth century. Another family noted here is the Schmied family of Pfaffendorf in an article by the volume's editor Monika Lustig, though this is confined to three natural trumpets.

Two linked articles, both illustrated with photographs taken by endoscopes, discuss the discovery of scrape marks inside the tubing of brass instruments and the possibility that these were made by slides. Dieter Krickeberg on scrapes from trumpet slides and Tom Lerch on scrapes more generally on brass instruments in Berlin. These suggest that there may be more slide trumpets surviving than the one Huns Veit, and even one possible corno da tirarsi. Clearly there is much more work to be done in this area and more experiments, for there is a number of alternative possible explanations for such marks. Nevertheless, this is an exciting new area for investigation and an exciting new method and technology.

These two articles complement a somewhat simplistic one on the history of the slide trumpet which does not mention the controversy over whether the thing even existed in the Middle Ages—I'm happy with the assumption that it did but there are others who are not and there has been enough discussion in, for example, Early Music that it is silly not even to say that the controversy is there.

Among several articles on the trombone, Stewart Carter discusses the problem over whether it was in A or B♭ in closed position and when (and if) it changed from the former to the latter. He says, towards the beginning, that "some theorists, notably Michael Praetorius and Daniel Speer, remark that the trombone's first position (or first 'draw') is obtained with the slide not fully closed, but extended by the width of two 'Querfinger'". This he proposes to ignore "because it represents an inconvenient intrusion", but surely it is the whole kernel of the argument. If a position two-finger-widths from fully closed is regarded as first position, that on a B♭ trombone would sound A. So 1st position, for us, is fully closed, giving a nominal note of B♭ but in the early and mid Baroque, certainly down to Speer in 1697, they preferred to have the slide an inch or so open, giving a nominal note of A. Thus the two are the same and there is no need for argument.

Much more important is a very densely argued article by Arnold Myers on the parameters for description and discussion of trombone types, and especially for defining differences between what we tend to call sackbuts and what we might better call trombones. He has established six parameters: a ratio of conicity, being that of the cross-sectional area of the windway at the mid-point of the length to the minimum (usually shortly below the mouthpiece socket); another of cylindricality, being the proportion of the overall tube length at which that same area doubles that of the midpoint; one that is rather hopeful for the earlier period, being the cup volume of the mouthpiece, a) if it exists, and b) (I would hope though he doesn't say so) if there is any indication that it might be original; the next the overall air-column length with the slide etc closed; the bore diameter at the midpoint of the length, with slide trombones usually the bore diameter of the ascending slide-leg; the last one that he calls the Upeak, which is calculated from the curvature of the bell and is the peak value of what is called the 'horn function' of the bell. Two further points are the position of that peak relative to the end of the bell, usually a little way in but with narrow-belled sackbut possibly even just beyond the end of the bell, and the diameter of the bell at that point (which in the latter case can be extrapolated). The results of these parameters are given in three tables of 62 trombones of various sizes, types, and dates, from the 1557 Neuschel to a 1978 Conn, and including both valve and slide instruments from alto to bass. The results are extremely interesting and my only real concern is whether anybody other than Arnold is going to have the patience, and the skill, to put this system to the use that it deserves. Even with
my own dozen or so instruments, I doubt I
could do it, for it requires a greater ability to
measure precisely than I suspect I have, and
certainly greater mathematical competence —
even to get this far I had to email Arnold for
some explanations.

I think this is long enough to demonstrate
the importance for brass scholarship of this
conference report, even though there are sev­
eral articles still unmentioned. One could wish

that more were available in English, but these
were the languages of the conference, and each
is published as it was delivered. Those authors
with English names can be taken to be printed
in English; those with German names in Ger­
man.

One should note, also, that the price is very
reasonable for so much material and that there
is a comprehensive index, a useful and very
rare facility for such publications.

The first six instalments of the Viola da Gamba Society's *Thematic Index of Music for Viols*, compiled by Gordon Dodd, appeared between 1980 and 1992. Work on the project is continuing, and it is now intended that further instalments and amendments will appear both in print and on-line. This new *Index of Manuscripts* is intended to complement the Thematic Index by surveying the sources themselves. In contrast to the Thematic Index, the emphasis is not on the music but on describing and listing the contents of each source, and providing information on their provenance and make-up. The format of the entries is exemplary. The opening description of each source gives the approximate date, the number of leaves, foliation or pagination, and a note of blank music pages. In identifying scribal hands the efforts of all previous researchers have been drawn upon. In several of the sources more than one scribe is represented, and in not all cases is there unanimity of opinion as to their identities. The Index is generous in the information it gives on the paper of the manuscripts. After details of format and page size, watermarks are described and located, referring to the first of two valuable appendices, on Watermarks and Paper Types (amounting to 58 pages). The brief introductions there to papermaking, and especially to the seventeenth-century English trade in ruled paper, are valuable beyond the confines of the viol consort repertoire. The principal types of watermark are reproduced and, using a classification system devised for the purpose by the authors, an impressively large number of key measurements are given for each. This appendix has its own bibliography. The rastrology (the size, number and spacing of the ruled staves) of each source is recorded, from which it has been possible to conclude that there was a relatively small number of merchants who ruled paper using composite rastra, drawing from two to six staves at once. The collation of each manuscript is given (where present condition permits), bindings are described, and each entry ends with a note of provenance and bibliography.

The tabular inventory of each manuscript lists composers, numbering systems, titles, inscriptions, scoring, and pages or folios. Reference is made to concordances and to the Viola da Gamba Society's *Thematic Index*. If I have one regret it is that more information is not given about the scoring of individual pieces. The tuning of lyra viol parts is given in French tablature letters, but the clefs of pieces not in tablature could relatively easily have been included in the tables, and would have added greatly to the usefulness of the Index. The keys of individual pieces are given for a minority of sources only.

One of the most valuable aspects of the volume is the second appendix, a selection of eighty facsimiles chosen so as to represent each of the main scribal hands in the manuscripts. Considerable progress has been made in identifying these scribes in recent years, and this convenient reference will surely assist in identifying others. The examples include lyra tablature (pp. 318 and 385-7), solo lyra music in staff notation (p. 336, from Printed Book mus. 184.c.8 in the Bodleian Library, Oxford; not one of the manuscripts indexed, but chosen to illustrate John Jenkins's hand), barred scores (pp. 323, 354) and an especially rich variety of keyboard parts (pp. 331, 334, 337, 341, 351, 358-60, 365-7 and 369). Unfortunately the page numbers in the List of Facsimiles (p. viii) are faulty between pages 328 and 336, as are some of those in the index to the volume for the same facsimiles. The otherwise excellent index lists only names, places and manuscripts, not titles or other subjects, so a musician's search for *In Nomines* (numerous) or settings of 'Io son ferito' (p. 83), for example, or an instrument historian's for 'Harpsecord' (p. 120) or 'great Dooble Basse' (p. 200), has to be conducted laboriously — though the labour is always a pleasurable and rewarding one.
Response to Eph's Response to Lewis's Comm. 1721

Eph is, from his second paragraph onwards, responding to correspondence between him and me, and as much of his reference to types of scholar, other than his ideal, that is not addressed to John Catch, refers to me.

A major problem between us is that since Eph is always right he finds it difficult to appreciate the other chap who puts up strong arguments and good evidence which doesn't happen to match what Eph already believes. I'm not saying that I believe it either, till it's been proven, but I'm happier than he seems to be to let it ride a while and see if the evidence hangs together before shooting it down. Admittedly such caution sometimes makes one lose out. Way back in 1975 when I was writing my *Medieval & Renaissance Instruments* I wasn't happy to accept the vague rumours that Eph was happy with about citoles and gitterns, so I got them the other way round, the wrong way. I wanted to see the evidence and assess it first, and Laurie Wright didn't publish in *GSJ* till after I had.

But that's not really relevant. What is relevant is this matter of reviewing past papers which we have not been invited to review. It may be that English custom differs from American in this area, but I have been writing reviews since about 1950 and the principle that was dinned into me right from the beginning was that you only write a review of something which you have been invited to review. You cannot go to a concert (that's where I started writing reviews), come out saying that it was wonderful (or a stinker) and ring up your editor and ask if you could write a review. The answer was 'no'. And there were three reasons. One was that the artist or management (or in Eph's case author or publisher) had not asked for your opinion, and this was always their liberty; they were fully entitled to invite everybody else's opinion but not yours (I did already have a reputation as a fairly fierce critic!). Another was that if they'd not sent you free seats or a free book, why the hell should you give them free publicity? The third was the legal one (which Eph dismisses rather cavalierly, forgetting some historic cases) where an unfavourable review can lead to a writ if that review were not invited. A fourth was custom: we didn't do that sort of thing.

Of course, once a review has been solicited the field is wide open, which has led to some past reviews of mine of which some people still remind me. The invitation is seldom personal (I do occasionally get sent a book direct with a request to review it and I do then sometimes ask round some editors to see if they'd like a review); the invitation normally goes to the journal and the editor or review editor chooses a reviewer. But he can, as I have several times done here, ask others to join in. I've written several reviews here and ended with a request for other members to send in their own comments. This is fair (except they don't get a free book, which is rough) because it wasn't I who was asked to review it but FoMRHI.
What isn't fair, to my mind, is to pick up a book or an article from the shelf and write a review of it unsolicited. To me this is unprofessional conduct. It is especially unfair if the author is dead and cannot reply, and also because whereas it is standard professional practice to send the publisher a copy of the review as soon as it appears, of course that doesn't happen with an unsolicited review so that the author, if he is still with us, may not ever know that he has been attacked.

Scholarship (no, I'm not going to define it; the rest of us all know what it is) never stops, of course. But it progresses by discussing the subject, not by attacking the way it was written up. If one has opinions on a certain type of viol, and if one has new evidence to add to previous studies, from examining the objects themselves and from new and more detailed morphological, technological, dendrochronological, geobotanical, and other research, one writes a study, in which of course one discusses all previous publications on the material at issue. But one does not just review an article which does not fit one's own ideas.

This, incidentally, is why FoMRHIQ is not a peer-reviewed journal. In a peer-reviewed journal if your article does not fit the preconceptions of your peer reviewers, it doesn't get published. The history of scientific research is full of stories of groundbreaking research which was initially refused publication because it did not fit current thought. Of course you don't win all the time like that; we've published some crap as well as some good stuff, but we have published a lot of good material which might not have made it elsewhere.

Enough, probably. Eph and I are both boat-rockers but we go about it in different ways. We both stir up controversy and neither is afraid to say what we think about each other's writings (nor anybody else's). We were trained in different schools, I in the English scholarly tradition which savages a colleague in an article or review and then happily lunches with him, leaving him to prepare his vituperative response during the afternoon before we meet for dinner. This tradition does sometimes puzzle foreigners but it seems to work here.
Irving and historical scholarship
a lesson for music historians

A recent item in the news was that the Oxford Union cancelled a debate on whether it is right to restrict the free speech of extremists. The reason was a public outcry at the invitation to David Irving to participate. He is considered to be a controversial military historian who has recently lost a libel action against an American author who wrote that he was denying the Holocaust. The Holocaust was a planned systematic killing by the Nazis of large populations under their control that they considered to be undesirable. Irving has not directly discussed any hypothesis concerning whether the Holocaust happened. What he has done is to show that some of the evidence of planned mass extermination in concentration camps can be interpreted according to other scenarios. One cannot deny that these possibilities exist, but proper application of the methods of scholarship can show that his interpretation are less probable than the original ones.

Yet most historians have not quarrelled with Irving's methods. Objectively, it is always constructive to explore different interpretations of the evidence. What is needed though is an objective way to choose between them. Unfortunately, the only criterion for choice used by too many historians is consensus in the subjective judgements of the experts. They don't distinguish between an hypothesis which can reasonably explain all of the relevant evidence, and one that can't. An hypothesis that can deserves the respect of being a valid theory in scholarship (which can compete with other valid theories as candidates for approaching truth). An hypothesis that can't can only be suggestive, and shouldn't be taken seriously until a valid theory can be offered. In scientific scholarship, it is much more widely recognised that one piece of evidence unexplainable by a theory invalidates or 'falsifies' that theory. Without such an objective criterion for theory validity, these historians can only make subjective judgements between hypotheses, which is subject to fashions of thinking about the subject.

Irving cannot and doesn't argue that the mass exterminations didn't happen. His purpose is to argue against the hypothesis that the mass killing was purposely planned. The new evidence that he has presented is just as easily explained by this hypothesis as by his own (which is that it was not purposely planned). He dismisses, without offering reasonably probable alternative explanations, the considerable amount of evidence that it was planned. Thus his hypothesis is not a valid theory, and his contribution to historical scholarship is negligible. From how his work has been used, it is clear that he has been supporting the hypothesis, promoted by Nazi apologists, that the killing of civilians under their control by the Nazis during the 2nd World War was no more serious a crime against humanity than the killing of civilians by the Allies in their bombing. The seriousness of a crime against humanity is not an issue that historical scholarship is competent to address, so Irving has been using the methods of scholarship for a political and not a scholarly purpose.

Many historians consider that their job is to collect, sort and present the evidence, interpret that which is clear, and perhaps speculate about some of what is not. They deal with 'facts', and consider all generalisations that go beyond the 'facts' as mere speculations. They don't consider that it is their responsibility to produce theories to explain all of the relevant evidence, nor to explore different possible theories and objectively compare how well they can explain the evidence. They are doing research which may be important in advancing our knowledge of evidence, but without theories that fully explain the evidence in an historical context (that provide us with generalised knowledge), it is only research plus speculation, and is only half of what scholarship is supposed to do. Their lack of intellectual tools to distinguish with objectivity between theories, encourages others like Irving and some music historians, who marshal only the evidence that can be consistent with an hypotheses they believe is true, and in their publications (full of references, footnotes, etc), they promote these hypotheses as being knowledge produced by scholarship. But if such an hypothesis is subjected to the tests of theories in scholarship, it can often be shown to be invalid because it cannot adequately explain all of the relevant evidence, or it can be rejected because other theories can objectively explain it in more reasonable and probable ways.

The public outcry came from revulsion at Irving's political and moral position, attempting to excuse the Holocaust. It is a pity that this outcry was not joined by historians pointing out how his work does not meet the criteria of scholarly validity.
Double Chamfers

Shortly after being made responsible for recorder production and development in the Dolmetsch Workshop, fourteen year old Carl Dolmetsch set about making the recorder louder. He rightly claimed that the sweeter, softer sound of original recorders often failed to be heard when played with modern instruments. The reasons are not hard to find - modern instrument design has attached considerable importance to producing louder sounds as concert halls increase in size, and composers have responded to having more powerful instruments at their disposal. The efforts of Carl Dolmetsch certainly resulted in slightly louder recorders, but even so they are easily overcome by modern instruments. Today I meet professional recorder players who say that the louder the recorder is the better, and that it can never be loud enough!

The chamfers at the south end of the windway strengthen the tone considerably. Small chamfers, resulting in a thin sheet of air impinging on the labium edge, produce a sweetness and softness that is beguiling - Fig.1

![Fig. 1](image)

Making the chamfers bigger produces a thicker sheet of air impinging on the labium edge, which in turn produces a louder more powerful sound - Fig 2

![Fig. 2](image)
The question then arises - why not make the chamfers huge to achieve the really loud sound many performers are seeking? Makers soon discover why this approach doesn't work. Put simply, if the sheet of air is enlarged too suddenly with an oversize chamfer, it breaks up into a turbulent stream of air which causes the tone of the recorder to become unacceptably diffuse and breathy. But this problem can be largely minimised by allowing the sheet of air to become bigger not in one large increase, but in two stages. To enable this to happen, double chamfers are essential - Fig. 3

1. The breath enters the narrow windway and reaches point A as a compact sheet of air.
2. Continuing to move forward as an expanding sheet of air, it reaches point B, the end of the first set of chamfers, and has now increased to thickness X.
3. This now thicker sheet of air continues to move forward to point C and has now increased from thickness X to thickness Y.
4. This thick sheet of air now impinges on the labium edge.

If the double chamfers have been cut at the correct angles and sizes, the sheet of moving air retains its well defined shape and does not break up. A thick sheet of moving air puts more energy into the instrument than a thin sheet of air, resulting in a louder instrument. If the double chamfers are not correct, being too big, or containing the wrong angles for example, turbulence is introduced. And as already mentioned if very large chamfers are cut directly from A to C, the expansion in thickness of the sheet of air is too sudden, and it breaks up.
Readers may well ask if triple chamfers would allow the production of even louder recorders. I don't know - I haven't yet tried them! But I have found that rounded edges rather than chamfers give considerable problems - a slow speaking and noisy instrument.

FoMRHI Comm. 1764
A Synthetic Finish for Woodwind Bores
Andrew Colebrook

I have recently been experimenting in using a synthetic finish for the bore of recorders using Paraloid B72 as an alternative to oils, which take longer to give a suitable build up of material. B72 is a thermoplastic acrylic resin and is a methyl acrylate/ethyl methacrylate co-polymer applied in solution.

Museum conservators have used this product for a long time as a replacement for PVA. It is resistant to water, alcohol, oils (mineral and vegetable) alkalis and acids so it is an ideal finish. Although the literature generally describes the finish as less glossy than PVA, I find that it dries to a mirror-like shine when the bore is properly prepared. B72 is also fairly elastic so it will move in time with the bore without peeling off. If the instrument is made of a wood such as boxwood, which is notoriously prone to significant movement, an elasticising agent can be added. The finish can be applied clear or pigmented with almost all pigments. The material is very good at filling open grain, and as the layer applied is so thin, it doesn’t adversely affect the instrument’s sound. The finish can be used almost anywhere. For the outside of recorders, where a high sheen finish may not be required, French chalk or silica matting agent can be added to give a satin finish.

B72 comes in a pearloid form and has to be mixed with a solvent to dissolve it. This is best done overnight, since the material takes some time to dissolve, and good ventilation is essential. A large batch can be made up at one time, perhaps to a higher concentration, and kept in storage and diluted to the desired strength as required.

Determining the appropriate dilution requires some care; too concentrated a solution will be too viscous to work with whilst too dilute a solution will give a low build-up and require many applications. I have been using a 10-20% solution in toluene, which allows time for an even coating throughout the bore before it goes off. I have tried using acetone, the alternative solvent for B72, but found that the resulting solution went off too fast to be usable.

Before coating the bore, I have abraded the bore through many grades of wire wool from ‘0’ until I finished with ‘0000’ grade wire wool. I have applied B72 by pouring it carefully through the joint taking care to achieve an even coating. I then place the instrument aside for an hour to allow for complete drying. Two or three coats give a wonderful result.

As I have only started using it recently, I am unable to say what will happen to it in the bore after time. However for other uses it is reported as very stable and non-yellowing over time. B72 is also used as an adhesive.

B72 is manufactured by Rohm and Haas and it is available on the Internet at http://www.consem.com. And is available in the UK from Chermacryl Limited, 4 Station Court, Borough Green, Kent, TN15 8AD, England. Telephone: 01732 789900 Fax: 01732 789901.
I have recently made a reconstruction of Arnaut's clavisimbalum. Although very little information about keyboard instruments exists from the 15th century, in written form or extant examples, the manuscript of Henri Arnaut de Zwolle, c. 1440 in the Bibliothèque National in Paris survives as a unique and useful document from this period. My reconstruction is not intended as the definitive representation of the clavisimbalum, there are far too many ifs and buts for that to be possible, but actually making the pieces that Arnaut describes and adhering as closely as possible to the directions he gives perhaps helps to get nearer to his ideas and make changes and adjustments where details are not fully explained or are left unclear in the manuscript.

The section of the manuscript that describes the Clavisimbalum shows a plan view of the instrument and separate keyboard with drawings and descriptions of four devices for "attacking the strings". For the purpose of the reconstruction, only the description of the clavisimbalum and the first device were taken from Arnaut's manuscript.

The first of Arnaut's "devices for attacking the strings", "the first and best", as he says, is without doubt a plucking mechanism (See fig.1). The three dimensional effect of Arnaut's method of drawing shows that it is fitted with a pivoted tongue in a similar way to the modern jack. In his description of the construction of the clavisimbalum he seems to be describing an instrument specifically for the installation of this first device or forpex as he calls it. His descriptions for the assembly of this mechanism into the register (i.e. "by tilting" and "passing through notches in the wrestplank"), and its attachment to the tails of the keys clearly indicate that an instrument with this device was in his mind when he was making the drawings and descriptions. The clavisimbalum fitted with this plucking device might therefore be termed a harpsichord as we would understand it today.

Of over 31 illustrations shown in an article by Edmund A. Bowles entitled, "A Checklist of Fifteenth-century Representations of Stringed Keyboard Instruments", fourteen show instruments of harpsichord shape. Although somewhat smaller in overall size to the harpsichord we would recognize today these instruments have many similarities to the clavisimbalum described by Arnaut in his manuscript. All of the illustrations in Bowles' article show small
portable instrument. Several appear to be played in the vertical position perhaps strung around the players neck. Most show only the outline shape and some superficial decoration but three of the plates, 19, 20 and 27a (see figs.2,3,4) display some interesting details with a number of similarities to Arnaut's instrument and his mechanisms. From the information given in the manuscript the instrument in plate 19, dated 1465-8, bears the closest resemblance to the clavisimbalum. It shows a harpsichord in plan view which is small in comparison to the angel figure. Although the overall size of the instrument has probably been reduced to facilitate the composition of the sculpture the case sides appear to be quite thick and there is a raised section across the area of the registers. The bridge, which is clearly shown in this plate, runs parallel to the bentside and is positioned exactly as Arnaut describes it, (i.e. the arc forming the bridge line uses the same center as the arc of the bentside). Most interestingly, in the register gap, a row of quite thick marks show what might be taken to indicate the tops of the plucking mechanisms. The first device that Arnaut describes, when installed in its playing position, has a similar appearance to this thick line between the strings. The compass of the instrument works out to 16 natural keys, calculated by using the number of visible keys as a proportion of the distance between the key blocks. This is somewhat less than Arnaut's instrument which has 21 naturals, although the sculptor has, again, probably reduced the number of his keys in order to make the task of carving simpler. The number of slots in the register gap is coincidentally twenty-one the same number of natural keys as in the Arnaut instrument. Whilst it can be said that the instrument in the sculpture is not a precise representation of a harpsichord, the craftsman that produced this figure would certainly be working from an instrument that he had seen. Perhaps the strongest indication that this may be an Arnaut type instrument is the quite definitely horizontal nature of the marks in the register gap. Comparing Bowles' plate 19 with plate 20 dated 1468, is most intriguing. (Discounting the artists optical illusion in the casework) The lines in the register gap on this instrument project vertically from the soundboard and stop under what appears to be a jack rail that we might recognize today. An artist will generally give a fair...
representation of what he sees and the lines are clearly vertical not horizontal as would be the case with Arnaut's first device. It is, therefore, not out of the question to suggest that these lines may indicate a different type of plucking mechanism and that before the end of the 15th century a form of jack had been developed, perhaps using only the tongue and quilling, as shown in Arnaut's drawing of the first device. The harpsichord shown in Bowles' plate 27a and dated 1475-90 is less clear than the other two but here also the position of the jack rail is definitely below the level of the top edge of the case with the faintest, but certain, vertical lines projecting from the soundboard. The clavicytherium c. 1480 in the collection at the Royal College of Music, London has a plucking mechanism similar to the modern jack with the tongue enclosed in a small slot at the end of a thin strip of wood. It is guided through the strings by little pins and fitted to the keylever with a bracket arrangement. This instrument is very similar in shape to Arnaut's Clavisimbalum and within the dated area of the illustrations in Bowles' article. It has been established that the Clavicytherium is largely original so the jack arrangement might therefore be assumed to be 15th century. This might suggest that for a time both Arnaut's forpex and some form of the later type jack were in use in similar instruments, before the later type became standardized. Considering the early date of clavicytheria, (Paulinus refers to them in 1460) it is not impossible that the development of this instrument with its simpler plucking mechanism prompted the development of the later type of jack. By employing this new mechanism the number of moving parts and pinned joints would be reduced thereby improving reliability of action whilst the overall size of the instrument remained small.

Before attempting the reconstruction of the clavisimbalum it must be accepted that some aspects of the design have to remain conjectural based on iconographical evidence and deductions from Arnaut's text. The manuscript does not contain detailed information on how to build a complete instrument. The fundamentals are given such as the over all shape, the position of the bridge, the number of keys and the general principal of the plucking mechanisms etc. But, for example, the exact nature of the plucking device guiding system and the keyboard housing arrangements are not fully or clearly explained.

In the reconstruction of the Arnaut instrument the maker is guided into a natural order of assembly by the nature of the design. For this instrument, as in the later Italian tradition, the base board is the starting point. Once this is made, (in Arnaut's instrument the inferior fundus), the way to proceed is to make the wrestplank and all the frame components and lay them on the board during assembly. Once assembled, the central section of Arnaut's instrument containing the base board (inferior fundus), wrestplank and soundboard (fundo superori) is about 40 mm deep and surprisingly light in weight. It feels something akin to holding the sound-box of a stringed instrument. Most of the illustrations in Bowles' article show instruments with thick outer casework. Arnaut's only mention of side thickness is that between the superior and inferior fundi (the soundboard and baseboard). This he says is equal to the line OT and works out to about 18mm, which seems quite heavy. However if the top inside edge is beveled in a similar
manner to the liners of some later instruments the strength is retained whilst freeing up the
soundboard (See fig 5). He gives no instructions as to the construction of the outer case work,
which is obviously needed in order to give stiffness to the inner frame, other than to say that they
extend above and below the top and bottom fundi. Unlike his clavichord drawing where there is
a clear indication of the side thickness Arnaut gives no similar details about the sides of the
clavisimbalum.

The schematic nature of the manuscript drawing and the fact that the keyboard is drawn
separately from the plan of the instrument denies us any clue as to whether there may have been
a key well. In Bowles' article all but four of the harpsichords are depicted with cheeks to either
side of the keyboard. However Arnaut's clavichord drawings show the keyboards in position and
no cheek pieces in evidence, an arrangement which is confirmed by the clavichord illustrations
in the Bowles article.

The sections that Arnaut terms the, “lateral sides”, extend above the soundboard and below the
base board. His base board (inferior fundi) is therefore set above the level of the lateral sides
making the bottom an active component of the resonating chamber. This is a feature which may
have been carried over into later larger instruments as a number of other harpsichords are
constructed in this way. The early, c.1550 (possibly 1535 according to Barnes) Italian
harpsichord in the RCM collection has its bottom boards set 7mm above the lower edge of the
sides as does another anonymous Neapolitan harpsichord of 1537 in the Castello Sforzesco in
Milan and the anonymous Neapolitan harpsichord in the Museum of Fine Art, Boston. The
clavicytherium in the RCM collection also has a similar arrangement to the Arnaut harpsichord
with a sound box contained within the outer framework. The sides of the RCM clavicytherium
vary between 4.8 - 5.7mm in thickness. For the reconstruction, sides were made, as Arnaut says,
extending above and below the soundboard about 10mm thick following the shape shown in
plate 20 by Bowles (see fig.5). In his manuscript Arnaut mentions a chest covering the area of
the mechanism. He states that this goes down between the strings on the soundboard side and
down to the semitones (sharps) on the keyboard side. However none of the illustrations given by
Bowles shows any instrument with exactly this feature. Arnaut distinguishes between the part of the instrument behind what would be the jack rail area and that which extends from the housing of the mechanism to the extremity of the keys. He indicates a different dimension for these two areas. The plates, mentioned above, from the Bowles' article show the sides of the instrument raised at each end of the keyboard and register section. Considering the slightly later date of the illustrations than the manuscript it is possible that this apparently structurally unnecessary section is a remnant of the feature described by Arnaut, before the later modification to the jack rail that the plates seem to show.

The rather strange arrangement of the keyboard with doglegs and miss alignments must be due to faulty drawing technique rather than a representation of exactly how the keys were made (see fig.6). There seems to be no practical reason why the keys should be formed in this way and it is
difficult to imagine that Amaut could draw such an incongruous layout when the remainder of
the drawings in his manuscript are so clear. These apparent inaccuracies almost suggest that the
drawing was made by someone unaccustomed to the subtleties of marking out a keyboard,
where, to quote Hubbard, "a degree of tempering" is required. The keyboards of Amaut's
clavichords however are drawn accurately with each section of the key tails at right angles to the
length of the instrument and coinciding with the string and tangents position. These are then
joined by variously angled lines to the conventionally drawn keyboard. It seems inconceivable
that Amaut or his assistant!! was incapable of doing the same for the clavisimbalum.

The first of Amaut's devices, or forpex as he calls it, is a rigid unit (See fig.1). The two main
components of this assembly, the forpex and a kapsel-like pusher, appear to be riveted together
where it might be expected that the joint would pivot. Used as shown in the manuscript, the base
of the pusher will rub on the keylever top when the key is depressed. The slot in the key tail
would also need to be elongated to allow for the quite large to and fro movement as the key is
pressed and released. Perhaps this is why Amaut says it can be lined with brass to prevent wear.
For the reconstruction the joint between pusher and forpex was made to pivot with a brass pin
(see fig.7) Whilst Amaut gives details of the forpices and pivots for the keyboard he does not
say anything about guiding the keys at their tail end. The method of fitting the forpices into

---

\[ 
\text{Fig. 7.} 
\]

\[ 
\text{Brass pivot pin} 
\]

\[ 
\text{Hole for pin} 
\]

\[ 
\text{beneath key} 
\]

\[ 
\text{Detail of top of} 
\]

\[ 
\text{kapsel-like} 
\]

\[ 
\text{pusher} 
\]

---

\[ 
\text{Fig. 8.} 
\]

\[ 
\text{Hollow for iron pivot} 
\]

\[ 
\text{rod} 
\]

---

the wrestplank guides them to a certain extent but there is still enough lateral movement to cause
the pluck to be unreliable. If there is no other method of guidance the key and forpex assembly
will not work with any precision. As with the later type of harpsichord it appears that it would
have been necessary for Arnaut's forpices and keys to have some sort of rack type guidance system. In his description of the fourth device he says that the key must strike something hard to allow the top piece to jump towards the strings. This suggests that he used some kind of guide and stop system to provide accurate movement of the key levers. In the drawing of the fourth device a reduced area is shown at the tail end of the key which may have been intended to locate with a rack slot. For the reconstruction a rack of this type was made for the key tails and a similar slotted arrangement fitted to the belly rail for the forpices. They would then be pivoted at one end on the iron wire fitted to the wrest plank and guided at the other. For practical purposes the iron wire that Arnaut speaks of must have been something more substantial than wire as we understand it today. The forpices pivots around this "wire" which needs to be rigid enough to support the device with some precision. For the reconstruction a 6mm diameter iron rod was used, fitted into a small hollow made in the face of the wrestplank (see fig 8).

The layout on the underside of the wrestplank where the keys pivot is not made clear in Arnaut's manuscript. At one point he says that the fundum inferiorem goes up to the line BC and at another that the wrest plank is thinner in that area. It cannot be both. If as his description says the keys rock on a semicircular profile, "balance rail", this is presumably fitted to a baseboard in the keyboard area which is in turn fitted to the sides of the instrument. In the absence of a removable key frame about 15mm would be enough space above the balance pins to enable easy removal of the keylevers without need to thin the wrestplank. For the reconstruction this method was used leaving a removable section of the baseboard beneath the key tails to allow fitting of the pins through the feet of the forpices.

Arnaut gives no indication of the plucking material other than the triangular cornu mentioned on the second device. This has been translated to mean horn. The shape given in the manuscript would produce a rigid plectrum unlike the flexible traditional quill of the later jack. In other early keyboard instruments there is evidence to suggest that metal plectra were fitted and it is possible that the clavisimbalum was similarly voiced. The RCM clavicytherium has traces of brass plectra reported by Hipkins in 1885\(^1\) The Theeuwes claviorgan 1579 in the Victoria and Albert Museum has two jacks with iron plectra. O'Brien\(^4\) says that these appear never to have been disturbed so can be assumed to be original and that, "an instrument fitted thus would be better equipped to compete with the louder organ". For the reconstruction Delrin was used. It is proposed to try thin brass plectra at a later date.

The position of the bridge in Arnaut's drawing shows it close to the sides of the instrument in the bass and treble and makes no allowance for the liner to support the soundboard. This would have had a deadening effect on the tone as the bridge would effectively be held at each end. For the reconstruction sufficient room was allowed around each end of the bridge for it to work more efficiently. This was achieved by placing Arnaut's plan within a slightly larger casework. Using Arnaut's geometrical instructions for marking out the plan of the clavisimbalum (See manuscript text below) and, as the basis for the octave span, Stewart Pollens suggestion for the width of the clavisimbalum\(^5\), (i.e the width of 21 naturals from the keyboard of the 1581 Hans Ruckers virginal, 502mm) gives an Arnaut 'unit' of 62.75mm. The resulting scale of the clavisimbalum is short, c\(^5\)= 235mm (Italian average, 350mm for iron, 270mm for brass), and the scaling plan is not of Pythagorean proportion, the bass strings being considerably shortened. This would indicate a higher pitch and after some experimenting it was found that the instrument needed to be about a 4th higher than a=415\(\text{Hz}\) to produce a satisfactory tone especially in the short bass strings. Referring to the RCM clavicytherium in his article in the New Grove Denzil Wraight suggests that these small instruments were about a 5th higher.
than the later 16th century harpsichords. Arnaut mentions either brass or iron strings so clearly the string material was given no particular consideration, however the need for two different materials is demonstrated in the tables below. Above c" iron had to be used as the tension in this section was higher than brass would allow. Tuning was made a 4th higher giving a=554Hz.

THE STRING LENGTH, FREQUENCY AND TENSION TABLES

The table below shows the note, length and frequency in Hz. for each string.

<table>
<thead>
<tr>
<th>Pitch</th>
<th>a' = 554Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOTE</td>
<td>LENGTH</td>
</tr>
<tr>
<td>B</td>
<td>686</td>
</tr>
<tr>
<td>c</td>
<td>650</td>
</tr>
<tr>
<td>c#</td>
<td>615</td>
</tr>
<tr>
<td>d</td>
<td>586</td>
</tr>
<tr>
<td>e</td>
<td>558</td>
</tr>
<tr>
<td>e#</td>
<td>533</td>
</tr>
<tr>
<td>f</td>
<td>510</td>
</tr>
<tr>
<td>f#</td>
<td>488</td>
</tr>
<tr>
<td>g</td>
<td>468</td>
</tr>
<tr>
<td>g#</td>
<td>449</td>
</tr>
<tr>
<td>a</td>
<td>431</td>
</tr>
<tr>
<td>b</td>
<td>412</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table below shows the note, length and tension in kg. for each string. Change of material and wire diameter shown in brackets. Iron is required above c". B = brass, I = iron.

<table>
<thead>
<tr>
<th>SIZE</th>
<th>NOTE</th>
<th>LENGTH</th>
<th>TENSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>B(0.27)</td>
<td>B</td>
<td>686</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>c</td>
<td>650</td>
<td>2.28</td>
</tr>
<tr>
<td></td>
<td>c#</td>
<td>615</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>d</td>
<td>586</td>
<td>2.34</td>
</tr>
<tr>
<td></td>
<td>e</td>
<td>558</td>
<td>2.38</td>
</tr>
<tr>
<td></td>
<td>e#</td>
<td>533</td>
<td>2.10</td>
</tr>
<tr>
<td></td>
<td>f</td>
<td>510</td>
<td>2.15</td>
</tr>
<tr>
<td></td>
<td>f#</td>
<td>488</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>g</td>
<td>468</td>
<td>2.28</td>
</tr>
<tr>
<td></td>
<td>g#</td>
<td>449</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>431</td>
<td>2.44</td>
</tr>
<tr>
<td></td>
<td>b</td>
<td>412</td>
<td>2.11</td>
</tr>
</tbody>
</table>

Using the formula above to calculate the string tension, a graph of tension curve was produced. English Brass and English Iron from Malcolm Rose were used for stringing. Iron, Average density 7769 kg/m³, Brass, Average density 8536 kg/m³.

\[ T = \frac{(FDL)^2T}{2k} \]

k = density of string material

The table below shows the note, length and frequency in Hz. for each string.
CONCLUSION

When the reconstruction is played the bottom can clearly be felt to vibrate so if this was the original intention it certainly works. Although many points in the Arnaut reconstruction remain conjectural once the nature of the missing information had been established the mechanism worked very well. Making the forpex in exactly the way that Arnaut depicts with a rigid, apparently riveted, pusher rod (kapsel) would have made it impossible to fit it through the register gap that he describes (one unit). Pivoting the pusher on the forpex allows it to drop through the gap of one unit width, but only just. The general impression of the action suggests that wear would very quickly become a problem. With so many joints and bearing surfaces the instrument would soon develop a rattle. The main area of wear would most likely be the key tail where the end of the pusher passes through. Arnaut says to line this with thin brass. This was possibly a brass plate around the oblong slot for the feet of the forpices, laid on top of the key it would take the main force when the key is depressed. This area is the most unsatisfactory part of the action. Arnaut states clearly that little cotter pin pass through the foot of the forpex beneath the keys and this produces an imprecise connection. A better solution would be to pin the joint through the key. This would integrate the three components, key, pusher and forpex making a smoother connecting rod action eliminating any slack with it’s potential to rattle. The other, pinned, joint and the rack guide works well but once the action is assembled there is no provision for adjusting the height of the plectrum other than the back touch. This makes voicing an awkward operation and accurate drilling and assembly essential in order to position the plectrum in just the right place beneath the string.

Arnaut describes the keys as rocking on an iron wire against pins passing through the keys with a semicircular piece beneath. This is very similar to the clavichord of c.1620 owned by Dr. Roger Mirrey of London. In this instrument the balance pins are also in a straight line but instead of an iron wire twisted gut is used against the pins.

The light weight of the action was not enough on its own to return the keys and in order for them to balance it was necessary to add a small lead weight to the tails of the naturals. In addition to this the friction in the system with all the moving parts caused the action to catch up and jamb. So, after fitting all the components as accurately as possible it was necessary to go through everything again introducing a little more clearance. In addition all the touching surfaces were rubbed with a soft lead pencil as a lubricant, this improved the whole action. In the manuscript Arnaut says that the first device can also be made of brass which would remove the key balance problem. All this may make the clavisimbalum sound ‘difficult’ but this is not the case. Once the teething troubles were overcome the action was smooth and light. The instrument has a clear voice, crisp and bright with plenty of volume. The buzz on the plectrums return without damping does not intrude as one might have expected. Overall it makes a viable keyboard instrument well able to hold its own with other early instruments.

THE MANUSCRIPT TEXT

For ease of reference during the reconstruction the following working outline was extracted from the translation of the manuscript by Lewis Jones and the book, “The Early Pianoforte” by Stewart Pollens.

The principal device for attacking the string.
The first jack system and the best. This is the jack which is suspended from the wrest plank by means of an iron wire passing in the slits of the register, and its tail crosses the bottom and extremity of the key by passing through a mortise, and it is pierced by a hole under the key and
we give here two diagrams of this jack, so that one can see the two faces and it should be made of good wood or better, in brass.

The bent finger of the front part of the jack is engaged in a vertical slot formed in the register: an iron wire crosses the finger and the slot (which acts as a guide to the jack) and allows it to pivot. This method (a) guides the jack well and prevents lateral displacement, (b) when one removes the pin for regulating, it prevents it falling into the housing of the mechanism.

**Construction of the Clavisimbalum:** (See fig 6 for Arnaut's lettering system)

For the construction of the clavisimbalum trace the line BC of a length equal to the width we would give to the instrument and divide the line into 8 equal parts. The line AB is equivalent to 4 of these units, the line CD to 13, the line DE to one and the line EF equally to one. Then trace a straight line FA and having placed the point G at its center, then draw the straight line CG, next on the line CG take 8 parts going from C to H [the line CG is first divided into 9 parts, Arnaut means 8 of these parts] and trace the segment of a circle that passes through the three points FHA, [by construction this produces an arc of 945mm radius] and starting from the center of this circle describe the bridge EIK and the segments of the circle neighboring the bridge are not equidistant, because the upper part of the bridge must be wider/thicker and higher than the lower. And at the point where the line YA traced with scriber cuts the line CG will be the center of the principal rose indicated by M. And starting from this center describe a circle the radius of which is one unit and this circle will be the principal rose. And two thirds of the diameter of the principal rose will be the diameter of the two other middle sized roses, as for the little roses one can make them as one pleases and even if one wishes without any openwork decoration, and one should place between the roses, and equidistantly bars to the number of 4, and these bars must be stuck first to the soundboard that is after, by means of points, they have first been fixed in their respective positions on the lateral sides. Likewise the bottom board will be extended up to the line BC, as for the soundboard it will be extended only as far as the housing for the mechanism, that is to say up to the line NO; NOPQ is thus the housing of the mechanism, PQCB the width of the wrest plank, and the line RS will be the wire in the middle of the wrest plank, over which will pass the strings, and in its lower part that is to say at the side of the line CB, the register will be thinner so that the pivots can be placed there, likewise the line BS which is equal to half a unit represents the distance between the two fundos, and the line BQ is the width or height of all the lateral sides up to the housing of the mechanism; the line OS is the width or height of the lateral sides after {depuis} the housing of the mechanism up to the extremity of the keys, and on the adjacent part of the sides it is necessary to construct a square box the fore part of which goes down between the strings, while the rear part descends as far as the semitones. As for the thickness of the wrest plank this will be only the distance between the fundum inferiorem and the fundum superiorum. Likewise the thickness of the lateral sides situated between the two fundos will be equal to the line OT. And the exterior lateral sides, in addition to the dimension that has just been mentioned, will be extended below the fundum inferiorem, and this because the keys will be situated below the fundum inferiorem. And the jacks having been put in place by a tilting movement will be placed in their housing and they will be connected to the wrestplank by an iron wire, and they will be suspended from this wire by a certain slot contrived for the purpose so that one can take them out very easily. Likewise the line VX drawn beneath the fundum inferiorem will be a wire of iron or of fairly thick brass, and the key will turn on this when ascending and descending, and opposite this said line at the part of the fundi inferiores which goes from the front to the housing of the mechanism, one will fix little pins which cross the keys [these pins are the key lever balance pins], and then the board overlapping the lower part of the keys will have a piece of semicircular profile stuck to it [this is the balance rail] so that the movement of the keys is not hampered by the fundos. Next the keys will have oblong
slits in their extremities; the feet of the jacks will penetrate through these and through the fundum of the housing of the mechanism, and these feet are pierced with a hole [the jack is then secured to the key tail with a pin through this hole] and these oblong slits may be garnished with a thin sheet of brass so that they do not wear in use.

Notes
1 Bowles, page 11.
2 Wraight, page 180. Ref. To, “manuscript treatise of Paulus Paulirinus of Prague (c1460)”.
3 O’Brien, page 28
4 ibid. page 28.
5 Pollans, page 19
6 Wraight, page 181-182
7 Barnes, see bibliography.

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Pollens, Stewart., The Early Pianoforte, Cambridge, 1995


Sources of Bowles’ illustrations;
Plate 19: Manchester Cathedral, Carved Musician-Angel (wooden corbel at nave ceiling). Date. 1465-68.

Plate 20; Paris, Bibliothèque Nationale, MS fr. 331, fol. 145v. Guillaume Fillastre, Istoire de la conquête du noble et riche thoison d’or. Date. 1468.

Plate 27a; New York, Pierpont Morgan Library, MS M834, fol.25. Book of Hours (Fouquet Workshop). Date 1475-90.

For more details of the clavisimbalum look on my web page from August 1st. 2001
www.harpsi.co.uk,
Some theory on pitch instability, inharmonicity and lowest pitch limits

There have been two pitch pathologies of vibrating strings discussed. One is pitch instability, where the pitch of a vibrating string varies noticeably with the vibration amplitude (i.e. how hard it is played). Then the pitch of a plucked string drops as its amplitude decays, and the pitch of a bowed string varies with the velocity of the bow. The other is inharmonicity in the string's vibration, where the frequencies of the harmonics deviate from being multiples of the frequency of the fundamental. A little inharmonicity in the sound changes the timbre in a way that can be considered attractive (as happens with the sound of the piano), but increasing inharmonicity reduces the number of audible harmonics (by a phase-cancellation process), which eventually makes the sound too dull and unfocused to be musically useful. How much of either of these phenomena is too much is a matter of aesthetic response. There are cultural norms about aesthetic response, which can (and did) vary historically, and these norms can be estimated given the right kind of evidence. The main point of this theory is that once this limit is found for one example in a musical culture, it can be extrapolated by calculation for others.

In our 1974 GSJ article 'Strings in the 16th and 17th centuries', we showed that in pitch instability (due to string distortion), the frequency change ($\Delta f$) divided by the frequency ($f$) equals a quarter times the ratio of the elastic (or Young's) modulus ($E$) divided by the string stress ($S$), times the ratio of the maximum stretch of the string due to strong playing ($\Delta L$) divided by the vibrating string length ($L$). In symbols only, $\Delta f/f = (1/4)(E/S)(\Delta L/L)$. The string stress is the string tension ($T$) divided by the load-bearing cross-sectional area. That area is $\pi D^2/4$, where $D$ is the diameter of the whole string if it is all of one material and all of it bears the load, and is only the diameter of the core of a wound string. The maximum stretch divided by the vibrating length ($\Delta L/L$) for a plucked string is $[l/(2(r-r^2))][d^2/(L^2)]$, where $r$ is the fraction of vibrating length that the distance of the plucking point from the bridge represents, and $d$ is the initial displacement of the string at that plucking point. For the bowed string, $r$ is 1/2 and $d$ is the displacement at the mid-point of the vibrating length. Let us confine ourselves to uniform strings and use the Mersenne-Taylor formula to substitute for the tension, $T = \pi r^2L^2D^2$, where $\pi$ is the ratio of the circumference and diameter of a circle, and $p$ is the density. Then the pitch instability ($\Delta f/f$) equals the product of a constant ($1/32$), times a term of properties of the string material ($E/p$), times a term of how the string is used on the instrument $[l/(f-L^4)]$, times a term of how the string is played $[d^2/(r-r^2)]$. In one experiment, we found that to our modern ears, the maximum pitch instability we found acceptable was about a third of a semitone, or $\Delta f/f = 0.06/3$ or 0.02.

In the inharmonicity of a uniform string, the real frequency of the harmonic called 'the nth mode' (the fundamental is the first mode), which we represent by $f_n$, divided by the in-tune frequency of that harmonic, which is $n$ times the fundamental frequency ($f_1$), equals $1+Bn^2$, where $B$ is the inharmonicity constant. In symbols only, the inharmonicity of the nth mode $f_n/(nf_1) = 1+Bn^2$. The constant $B = (\pi^2/32)(D/L)^2(E/S)$. If, as above, we substitute for the string stress, we get $B = (\pi^2/32)(D^4E)/(L^2T)$, and if we then substitute for the tension using the Mersenne-Taylor formula, we find the inharmonicity constant $B$ to be equal to the product of a constant ($\pi^2/128$), times a term of properties of the string material ($E/p$), times a term of how the string is played $[d^2/(r-r^2)]$. In one experiment, we found that to our modern ears, the maximum pitch instability we found acceptable was about a third of a semitone, or $\Delta f/f = 0.06/3$ or 0.02.

Typical values for historical string materials are:

<table>
<thead>
<tr>
<th>Materials</th>
<th>Elastic modulus ($E$) (GPa/Pa)</th>
<th>Density ($p$) (Mg/m$^3$/Kg/m$^3$)</th>
<th>Ratio ($E/p$) (m$^2$/sec$^2$/10$^6$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>low twist gut</td>
<td>6</td>
<td>1.35</td>
<td>4.4</td>
</tr>
<tr>
<td>gold</td>
<td>78</td>
<td>17</td>
<td>4.6</td>
</tr>
<tr>
<td>silver</td>
<td>78</td>
<td>10</td>
<td>7.8</td>
</tr>
<tr>
<td>copper, brass</td>
<td>100</td>
<td>8.8</td>
<td>11</td>
</tr>
<tr>
<td>iron, steel</td>
<td>200</td>
<td>7.8</td>
<td>26</td>
</tr>
</tbody>
</table>

Here, Pa is pascals, GPa is Gigapascals, Mg is Megagrams, Kg is Kilograms and m is metres.
We can see from the above table that, of these materials, gut (the measurement here is our own) is the least susceptible to these pitch problems, and iron and steel are the most susceptible. If we keep all of the other factors the same, the lowest useful frequency drops by half an octave (a factor of $\sqrt{2}$) for each drop by a factor of 2 in $E/p$. We found that the elastic modulus of high-twist gut is about half that of low-twist gut, and that of roped gut is about half that of high-twist gut. This corresponds with our practical experience with low pitch limits of gut due to inharmonicity, and is consistent with the historical expansions of instrument ranges.

For a particular string of a particular material on an instrument, we have a fixed $L$ and (usually) $r$, and we can see that the the lowest acceptable pitch frequency is proportional to $d$ or $D$. With the inharmonicity equation, there are three independent variables $D$, $f$ and $L$, so to get a relationship between two, we need another relationship. One such is that for balance in families of the same type of instrument, the string tension tends to be proportional to the string stop $L$. Then from the Mersenne-Taylor formula, $D^2$ is proportional to $1/f^2L$. For constant inharmonicity, $D^2$ is proportional to $f^2L^4$. Thus $1/f^2L$ is proportional to $f^2L^4$, so $f^4L^5$ is constant, with the result that the lowest usable pitch, $f$ is proportional to $L^{-5/4}$ in the family of instruments. I have used this relationship in deriving the string stops of some Renaissance and early baroque instruments using the maximum ranges of instruments in the family from the information provided by Praetorius.

If the tuning of a member of the family has a lowest pitch that is lower than that given by the above relationship, its lowest string can be made to conform to the inharmonicity limit by using a thinner one. From the inharmonicity equation, for every semitone that the lowest pitch needs to be lowered, the diameter $D$ has to be decreased by 6% from what it would be for normal balance on that type of instrument. That lowers the tension, which tends to be proportional to the sound energy output. The derivative of the Mersenne-Taylor equation is $\partial T/\partial f = 2\partial f/\partial L + 2\partial L/\partial f + 2\partial D/\partial D$. The tuning pitch and the string stop are unaltered, so the relative decrease in tension ($\partial T/\partial T$) is twice the relative decrease in diameter ($\partial D/\partial D$). Thus, for each semitone that the inharmonicity limit has to be lowered to meet the tuning pitch, the sound energy output decreases by about 12%. Such a weaker lowest string can be tolerated in a smaller member of a set that plays together because notes on that string are rarely exposed in the ensemble. It would probably not be tolerated on a bass member of the set or on a member that plays full-range solos.

Near the inharmonicity limit, the hiss associated with bowing a thick gut string includes a wide range of frequencies, including the missing harmonics. If the brain is convinced about what the fundamental pitch of the note is, it is possible that it can extract those harmonics out of the hiss, and thus 'hear' a more focussed sound. The same can happen with the plucking noise heard when a string is plucked particularly near the bridge. Plucking at that place also helps because it emphasises whatever harmonics remain in the vibration.

When a second string an octave higher is played together with a string near the inharmonicity limit, this can be heard as one string with the missing harmonics being physically supplied by the octave string. For this to work, the ear needs still to be convinced that the low string still has a recognisable pitch. By comparing the lowest pitches of instruments with an octave-pair lowest course with those with a single lowest string, we find that an octave pair lowers the lowest pitch by a tone. On early baroque lutes, the thick strings of the low octave pairs were considerably thinner than that needed to give a sound output that would properly balance with the treble strings. This indicates that pitch clarity on the low-octave strings was more important than full sound output, and that the high-octave strings contributed strongly to balance as well as to missing harmonics.
I have met many older musicians who started their playing of music using gut strings. They usually consider that modern strings are better in every way, and gut is better forgotten. But the early music culture (at least amongst bowed string players) insists that gut strings, being authentic, must be better. Most are willing to endure the less stability and durability and greater expense of gut strings to use them as a badge of their making the effort to be authentic. Some though are quite set against gut (some because they take vegetarianism very seriously), which has led them to seek historically possible alternative materials or a modern material that produces a sound that is indistinguishable from gut. The lute players have gone further, attempting to convince the early music community that their plastic strings sound the same as early gut, which was better than modern gut.

In Comm 1744, Rakov describes his experiences with twisting alternatives to gut. I am glad that he mentions twisting fishing monofilament strings as emergency substitutions for gut. It works better than single monofilament for top strings of bowed instruments, probably because there is less tendency to squeal if the bow movement is not accurately perpendicular to the string. I suspect that this is the primary reason why single monofilament strings have not been used on bowed instruments. I have found the squeal to be an excitation of the longitudinal compressional vibrating mode of the string by the small component of the bow's motion parallel to it. The twisted fibre construction of a gut string is good at absorbing that vibration. A twisted monofilament also does this much more than a single monofilament. A thick rubber washer inserted under the string on top of the bridge does this for a metal string, and it might work for a single monofilament string.

Next Rakov reports making excellent strings by twisting nylon floss or thread under working tension, sealing them by soaking in something involving alcohol. It would be useful to others who might want to follow his lead if he went into more detail about his method.

Rakov then shifts his attention to bass strings for lutes and viols, where he feels that nylon floss with metal winding does not match the fine quality sound he was getting on his treble strings. When he twisted basses like he did his treble ones, they came out too thick, but he reports that winding with nylon on a thinner core, the strings came out just a bit thicker than metal-wound basses, while winding with cotton, linen or hemp the strings came out even thinner. If he was just reporting experiments using the materials at hand, there is nothing remarkable here, but if as he implies, he is reporting strings that truly balance with his treble strings in all playing circumstances, on bowed as well as plucked instruments, this is very remarkable indeed!

On the bowed string, with the same bowing speed, the sound output depends on the force variation that the string exerts on the bridge, which is proportional to the string tension, which is proportional to the weight per unit length along the string. The reason why metal winding and Peruffo's loading with metals and metal salts allow strings to be thinner is because the metal (or metal salt) is much denser than gut or nylon, so the string gets to the needed weight per unit length with less volume of material. But windings of nylon, cotton, linen or hemp are not any denser than the core, so if the overall diameter is less, the tension must be lower and the sound output less.

The situation is somewhat different with the plucked string. The sound output still depends on the force variation that the string exerts on the bridge, but that only depends on the maximum force of the finger on the string during the pluck. The displacement of the string is proportional to the plucking force and inversely proportional to the tension. With the same plucking force, lower tension leads to higher displacement, which leads to clashing between strings of a pair and between strings and frets. That displacement can be kept within limits with normal plucking force and low tension by plucking nearer the bridge. So lower tension basses can work on lutes, and the early bridge-hole evidence indicates that this was common.

Rakov appears to be learning how to play his lute with historically appropriate string tensions. His use of metal pigments with his windings is interesting and novel, but I doubt whether it increases the weight per unit length of his strings to a degree comparable with Peruffo's loading. I wish he would make and report measurements on his strings so that others can repeat what he has done and know that they are experiencing the same string properties that he has described.
The covering of strings by low-density materials might have an early European historical precedent. Praetorius’s wheel-bowed keyboard instrument the Geigenwerck had its heavier strings ‘made from thick brass or steel, wound with fine parchment; the bottom ones are nearly as thick as those of the great bass viol, since some go down to bottom FF and DD’. It is not clear whether the parchment was along the full length of the string, or whether it was just near the ‘bowing’ position (perhaps performing a function similar to that of the cotton on a hurdy gurdy string).

Rakov next discusses silk strings he made from silk thread bound by fish glue. Silk strings, especially treble ones, have durability problems (like gut strings), so he did not pursue these experiments, since it is a diversion from his original purpose of developing synthetic strings. Nevertheless, the rest of his Comm. explores fitting the historical evidence of string properties on the assumption that they were silk rather than the usual assumption that they were gut.

It would be fair enough if Rakov just showed how the various characteristics of strings mentioned by Mace and seen in pictures applied to silk as well as gut, but he goes further. By saying that some apply to silk and not to gut, he is suggesting that silk was the material of choice. This shows that he has not explored gut with any of the imagination, effort and friendliness that he has applied to gut substitutes.

It is true that when Mace did not name the string material in his Chap. VI, where he wrote about Minikins, Venice-Catlins, Lyons and Pistoy Basses. But at the beginning of the next Chapter (p. 70), when discussing placing the frets on the lute, he mentions the fretting of instruments ‘Stning with Wyar Strings’, which could be fretted accurately according to a Mathematical Rule, yet that way ‘will not hold exactly (always) with our Gutt-Strings…, but in regard to their so often being False, the Best way is to place your Frets as you Tune up your Lute, by your Ear’. Mace was here clear as to what the choices of string material were, and that choice did not include silk.

Another piece of evidence that Mace was not writing about silk strings is the various cautions he gave about avoiding moisture, ‘For moisture is the worst Enemy to your Strings’. The primary advantage of silk strings has always been that they do not lose strength when left for some time in 100% relative humidity, while gut loses about 30% in its tensile strength in those conditions (gut strings on instruments hanging on walls often break overnight when the temperature drops, increasing the relative humidity). Silk was clearly used as a string material at the time, since it was mentioned as a choice in Playford’s 1664 wound-string advertisement (though Goretsky’s original invention was wound on gut). Silk would be the material of choice where exposure to very high relative humidity was unavoidable. Most players were able to avoid this by following Mace’s cautions, and chose gut.

Amongst the string information in the Burwell manuscript is that lutes were strung with gut. Praetorius’s table of instruments (in his Chapter 1) distinguished between those strung with gut and those strung with metal. Dowland wrote that when one broke a string, ‘if it breake faseld at the end, then it is strong, but if it breake stubbed then it is weake’. He was not considering silk strings because that is the best way we have found to discover whether a string is gut or silk.

Rakov’s observations about gut are of modern commercially made gut, which is somewhat different from gut at different times in the past. What these differences are (and their significance) are part of another dispute with another group of anti-gut musicians, and need not be pursued here.

It is always worthwhile to explore alternative interpretations of the historical evidence, and Rakov is to be thanked for focussing our attention on silk strings. Though his theory that silk was generally the material of choice over gut is not valid, silk was clearly the material of choice by some musicians, and as stringing with it has not seriously been looked into in recent times, Rakov’s Comm. is a welcome start.
At the beginning of the 16th century, sets of viols evolved from the Spanish 15th century vihuela, the original size, double it, and some in-between, and sets of fiddles evolved with the original size, half it, and some in-between. The original vihuela had a string stop (nut-to-bridge distance) of about half a metre, and had a shallow flat body that was distinguished from previous fiddles by having a waist cut-out and by being made from separate pieces of wood glued together.

Sets of fiddles in these above sizes persisted in Italy and Germany throughout the century. An alternative round-backed pear-shaped carved body design was particularly popular in Germany during the first half of the century; that design would be identified as 'rebec' by most people nowadays, but in the 16th century, these were called only 'fiddles'. There is no original evidence of instruments called 'rebecs' being other than soloistic fiddles. Before the 16th century, according to Tintorius, the rebec was smaller than other fiddles. After the 16th century, Praetorius indicated that the French rebec was of the smallest fiddle size, with the tuning of the earlier Italian and German treble fiddles. During the century, Italian pictures also show larger rebecs, appropriate for the tuning of the alto fiddle. The stringing of rebecs are thus covered in the Italian and German stringing tables here.

Apparently, in the 1520's, the French adopted larger fiddles, covering a larger pitch range, making fiddles more like the more respected viols. They called these larger fiddles 'violons'. To get to violons from the original pitches, the treble and alto/tenor members of the set dropped a fourth, and the bass dropped an octave. These tunings remained till well into the baroque, but the sizes of the larger ones dropped when more elastic bass strings became available later in the 16th century.

We can estimate the range of string stops from the pitches of Renaissance fiddles by calculation from the ranges and string stops of fiddles discussed and depicted on scaled drawings by Praetorius. The ranges are different for different types of lowest gut string. At the original pitch standards, for the three tunings of Italian fiddles, the ranges were 22-27, 30-41 and 57-62 cm with high-twist lowest strings, which were used for most of the 16th century. For the Gerle German bass, the range was 52-55 cm. With catline lowest strings, which started to be used at the end of the century, the smallest string stop dropped to 17, 24 and 45 cm, with 42 cm for the Gerle bass. For the three tunings of French fiddles, the ranges were 37 (one size only), 51-56 and 101-126 cm for high-twist lowest strings, which were used up to about 1575. After that, catline lowest strings were used, especially for the lower two tunings, to make more manageable smaller sizes. Then the minimum string stops dropped to 30, 42 and 80 cm. The minimum can be reduced somewhat with thinner lowest strings, but with some loss of projection. This would be least noticed on treble and alto sizes.

The following tables are calculated according to the popular modern early music pitch standard of \( a' = 415 \text{ Hz} \). For a range of string stops (L) and string tensions (T), appropriate string diameters (D) are listed. At \( a' = 440 \text{ Hz} \), the appropriate tensions would be one column to the right. Originally, they were near one column to the left. An important innovation in these tables is the listing of the proportion (L/T) between the string stop and the tension. This allows choosing equal-tension string sets that will create a balance between the different members of a set by trying to keep that proportion as constant as one can. If one chooses non-equal-tension string sets, the constant proportion applies to corresponding string numbers.

It is hoped that this practical presentation of the stringing of Renaissance fiddles will encourage musicians and makers to explore this very attractive area of the history of musical instruments. The repertoire is the generally available vocal part music of the time, and we assume ranges without ledger lines. In the Italian and German tunings, all parts were played an octave higher than written, and the treble played parts in the C1 and C2 clefs, the alto and tenor played parts in the C3 and C4 clefs and the bass played parts in the F3 and F4 clefs. The lowest string on the bass is not required here and it would have been used for when transposition down was necessary or when dropping an octave was musically effective. In the French tuning, all parts were played at pitch, and the treble played parts in the G2, C1, and C2 clefs, the alto and tenor played parts in the C1, C2, C3, and C4 clefs, and the bass played parts in the F3 and F4 clefs. Again, the lowest string in the bass is not required, and it was probably used as were the Italian and German basses, with less need for transposition.
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### Notes

- **L** = string stop; **T** = tension; **L/T** = proportion of string stop to tension; **D** = diameter or ED
- Table is for a' = 415 Hz; for a''=440 T one column to right; original T one column to left
- For a well balanced set of fiddles, L/T should be kept as constant as possible
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### STRINGS FOR FRENCH RENAISSANCE FIDDLES (VIOLONs)
Early Soundposts and Bass Bars

This Comm is a compilation of information and theories from previous Comms plus a few new bits.

The earliest written evidence for a soundpost is from the end of the 16th century, when audiences at the Globe theatre were watching Shakespeare's 'Romeo and Juliet' (1592) and at least some were expected to recognise that the word was a musical term. Three musicians appear in the play, with names James Soundpost, Hugh Rebecke (the rebec was a soloistic bowed instrument that was replaced by the violin) and Simon Catlin' ('catlin' was the name of a type of thick gut musical string).

The earliest surviving physical evidence for a soundpost is the Ventura Linarol 1581 violin (Vienna Museum C96), which has a small parchment pad glued to the back that apparently has acted as a platform for a soundpost. Dendrochronological analysis has shown that the current soundboard is from after 1640, apparently a replacement. At the time of the replacement, we expect that bass bars were normally fitted to soundboards, but the surviving soundboard never had a bass bar since the gouge marks on the underside are too deep to provide a smooth enough surface for gluing a bass bar to. Thus it is most likely that the replacement was a copy of the original with no attempt at modernisation. The most straightforward interpretation of this evidence is that the parchment pad on the back is original, and it was for a soundpost.

In 1636, Mersenne wrote that in viols, a soundpost was placed under the treble foot of the bridge, and could be lifted up again through the soundhole when it had fallen down. It was the 'soul' of the instrument, and when fallen down, the viol lost its 'harmony'. Just before writing about the viols, he wrote extensively about the violons (the French fiddle family), with no mention of the soundpost or its contribution to the 'harmony'. This could possibly have been just an accidental omission, but it is more likely that Mersenne was not aware of the use of soundposts on violons. This could have been either because they did not have soundposts, or that there were soundposts but they were not obvious to the players because they were permanently installed. Though the violons illustrated by Mersenne were of design similar to Italian violins or viole da braccio, many illustrations of 16th and 17th century violons show a different design, with S holes (instead of f holes) and the bridge so far below them on the soundboard that there was no easy access through the holes to a bridge foot to install or adjust a soundpost.

It seems to have been known from the first half of the 16th century that inhibiting the motion of one foot of the bridge changed the balance between the strings on one side of the bridge and the other. The output on the side with the inhibited foot is decreased, while that from the other side is increased.

At their inception at the beginning of the century, we would expect that the soundboards of both violins and fiddles made for sets would have been flat, with cross-bars on each side of soundholes, as we suppose were on their ancestor, the 15th century Spanish vihuela. Soon, many were made with arched soundboards with no bars. Around the middle of the century, there was a fashion for soundboards that had both arching and cross bars. They were apparently deficient in treble response, so a bass bar was inserted between the two cross-bars to restore it (we have made copies of these, and once put the bass bar on the wrong side, resulting in the imbalance of poor treble response and enhanced bass). This combination of cross bars and bass bar is on surviving viols by Francesco Linarol and Gaspar Duifoprugcar. I know of viols by Heinrich Ebert and Georg Gerle with replacement soundboards which have traces in the sides that indicate that an earlier soundboard had cross bars.

On the Welsh crwth and several eastern Europe folk fiddles, a soundpost is an extension of the treble foot of the bridge that goes through a hole in the soundboard. Such an arrangement is seen on a viol in a 1536 fresco at Schloss Goldegg. Similar viols are depicted in woodblocks on the title pages of the copies in the Basel Universitätsbibliothek of the superius, altus and bassus part books of Reutterliedlin printed by Christian Egenolph in Frankfurt am Main in 1535 (RISM 1535 11). In these woodblocks, it seems that the two side of the bridge had different heights, which is a way to control the imbalance created by the soundpost. This interpretation of the Egenolph evidence is better than that which I offered in Comm. 840 (Q. 49).
Another piece of relevant evidence from the middle of the 16th century is that the smaller sizes of violons all had four strings, while those of fiddle sets from countries other than France had only three. So it is possible that what made a fourth string work on the smaller violons was that they had built-in soundposts. The need for fourth strings is clearly to fill the gap created when early in the century the French lowered the pitches of their smaller fiddles by a fourth, but they lowered the bass by an octave. I cannot think of another explanation for how this difference between fiddles in France and elsewhere was accomplished.

This interpretation of the evidence is basic to my theory on the origins of the violin. The singular term *il violino* first appeared in Italy in the final quarter of the 16th century. In that period, it referred to a soloistic fiddle that did not play with other fiddles. The *violino* quickly replaced the *ribechino* (rebec) as the primary soloistic fiddle. Its tuning was different from any of the other Italian fiddles, but was identical to that of the smallest (dessus or treble) French *violon*. It thus seems to have been an Italian adaptation of that French fiddle. When it appeared in Italy, superior bass strings of roped construction (called 'catlins' in England) had just become generally available and affordable. Thus with catlin bass strings plus the soundpost inherited from its French origin, it revelled in a very effective bass range for such a small instrument. As with the *viola bastarda* (a soloistic viol that appeared at the same time), the *violino* sometimes used variant tunings expanded in the bass. The musical function of the *violino* then was probably the same as that of the *viola bastarda*, which was to play highly ornate versions of popular polyphonic pieces.

In 1600, we first find that the *violino* played a treble part in an ensemble. My suggestion is that this transformation, from a full-range fiddle featuring the bass to a mostly treble fiddle, was due to the *violino* acquiring a bass bar. There is no evidence for the use of a bass bar on any fiddle before then. A bass bar enhances treble response, and its addition would rebalance the instrument while giving it the glorious treble voice we appreciate today.

Within a few years, *violino* players regularly worked in pairs. Some formed sets with three tunings, the top using normal tuning, the second using a low tuning. For the bass, it seems that a bass *viola da braccio* was converted to a kind of *violino* by adding a bass bar and soundpost and using catlin bass strings, and tuning it an octave below the normal *violino*. These sets competed with the sets of *viole da braccio*. The players of the *viole da braccio* set responded by dropping the smallest member of the set (the size of a later *violino piccolo* or of a modern 1/4 size violin), started to play at pitch rather than an octave higher, and adopted most of the modifications of the *violino* set. With these modifications, the *contralto* played the treble and the *tenore*, tuned down, worked better than tuned-down *violini* because they were larger. Within a decade the *violino* and *viole da braccio* players combined forces, with the *violino* players covering treble parts, which only they could play with their ornate flamboyant style, while all of the lower parts (the *contralto* then rejoined the *tenore* in tuning) were performed by the *viole da braccio* players. This became the standard Italian early baroque string band.
17th Century English Viols

This Comm is the essence of a recent lecture I gave. Much has appeared here before, but not all.

**Design, construction, pitches, sizes and types**

The usual viol body design had the sides curving continuously into the sides of the neck, had outward points above and below the waist, and C holes. A minority of viols had an alternative design, with the sides coming in perpendicular to the neck and an inward dent below it (like on the bandora), had outward points above the waist but not below, and had novel soundhole designs. These viols also usually had inward points at the maximum width below the waist (like on a bandora) and on both sides of the tail block, and occasionally below the inward dent above the waist.

Linen or parchment reinforced the glue joining the component pieces of wood in the back and in the belly. It also reinforced the glue joining the side components to each other when they met at corners, and joining the sides to the back (there were no corner blocks or wooden linings). The belly was glued to the sides with no reinforcements at all. Linen or parchment also often reinforced the weak upper-bout fold in the back caused by the scoring necessary for bending the fold.

Before the 1690's, with viols of all sizes, the belly was made of bent strips (or staves) joined together with glue along 4 joints. The two joints nearest to the centre went under the two feet of the bridge, and the bass bar reinforced one of them underneath. The other two passed near the thinnest part of the waist. The belly was generally uniform in thickness. It seems that the central stave and end staves were initially thicker than the intermediate staves. They were usually simply bent with a long iron and later carved to the final arched shape. The intermediate staves appear to have initially been at close to final thickness to ease more complex bending. Simple bending (with a long iron) first formed the general shape, and then scorching on the inside (with repeated application of a short curved iron) added concavity to create the final shape. Then the edges of the staves were planed to fit together and the belly was glued. The thicker staves were then carved to continue the curves of the intermediate staves to smooth arching curves, and to get to the final thickness.

By the 1690's, playing of viols in sets ceased to be popular, and almost all of the new viols made were of a small bass size, suitable for using a wound 6th string. On these viols, the number of joints between soundboard staves reduced to the two that went under the bridge feet. The central stave was still bent, but the rest of the soundboard was carved to shape. The special skills in bending the intermediate staves had been abandoned. Viol makers then mostly made the more popular treble, tenor and bass violins.

The belly almost always had two rows of purfling around its edges, and this is a major indication of a viol being English.

The pitch level that viol sets usually were tuned to was more than a tone below modern (a' = about 380 Hz), a pitch standard also followed by mean lutes and domestic singing, as well as viols in France, Italy and Catholic Germany. When playing without voices or lutes, a set could be tuned up to a minor third lower than this level. Solo bass viols usually tuned higher than the bass viols of sets, depending mostly on size. Many could also take part in mixed ensembles involving instruments, like fiddles and recorders, that usually played at a standard a tone higher.

The string stops (bridge to nut distances) of the members of a set of viols was about 80 cm (32") for the bass, 60 cm (24") for the tenor and 40 cm (16") for the treble (with the fingerboard length 2/3 that). By contrast the string stops of modern viols are about 70, 50 and 35 cm respectively. There were no English alto viols. The second bass of a set of six could be somewhat smaller than the first bass. A double bass viol with a string stop of about 100 cm was sometimes available.

There were a variety of sizes of smaller solo bass viols made for accompanying the voice and for playing the repertoire in tablature. The smallest of these, with a string stop often as low as 65 cm, was particularly popular earlier in the 17th century. It was called 'lyra viol' when it had the normal relative tuning modified by the 5th and 6th being down a tone and the 3rd up a semitone. Those made around
1610-20 had an additional set of 6 sympathetic metal strings tuned like the bowed strings. Later in the century, larger solo viols for playing from tablature (in a variety of tunings) were preferred, and any such viol was called a lyra viol. It had a typical string stop of 71-2 cm, two fret-lengths shorter than the bass viol of a set. The fingerboard length was less than 2/3 of the string stop. By the middle of the century, a new larger solo viol appeared. It was called 'division viol', had a string stop of 76 cm (about one fret length smaller than the bass of a set), and probably came from the violoncino, a successor to the viola bastarda in Italy, but with the body of a bass violin. Some English division viols retained the bass violin body design. The fingerboard length was more than 2/3 of the string stop. At about the same time, the lyra viol with additional metal strings was modified so that the metal strings, tuned in a diatonic scale, could be plucked by the left thumb, and it was called 'barytone viol'.

**Bows**

The stick lengths of bass viol bows tended to be the same as the string stops. The lengths of the bows for other viols were about half-way between their string stops and that of the bass of the set.

The only type of bow construction at the time had both ends of the hair attached to the stick, with the frog clipped in. In this type of bow, the combination of hair tension and stick wood stability was such that there was no need to unclip the frog. If in the passage of time, the hair tension slackened somewhat, it could be corrected by inserting a piece of card between the frog and the stick.

Robinson (1603) wrote that you should 'Hould your bow or stick, hard by the Nut of it, with your forefinger, above the stick, your second and third finger (in the hollow of the Nut) betwene the heire and the stick, and your little finger beneath the heire, slack quite from it'.

Late 17th century sources show the influence of the French school, having a finger on the hair. The finger pressed on the hair at the beginnings of notes to better control the emphasis (see below). Simpson (1665) wrote 'Hold the Bow betwixt the ends of your Thumb and two foremost fingers, near to the nut. The Thumb and first finger fastened on the Stalk: and the second finger's end turned in shorter, against the Hairs thereof; by which you may poize and keep up the point of the Bow. If the second finger have not strength enough, you may join the third finger in assistance to it; but in Playing Swift Division, two fingers and the Thumb is best.' Mace (1676) quoted this and added: 'This is according to Mr. Simpson's Directions. Yet I must confess that for my own Part, I could never Use it so well, as when I held it 2 or 3 Inches off the Nut (more or less) according to the Length or Weight of the Bow, for Good Poyzing of It'.

It is thus likely that the majority of the surviving music for sets of viols, being earlier in the century, was originally played with a bow hold in which the hair was not being touched by a finger.

**How viols were sounded**

There is no known English evidence on this, but Mersenne (1636) discussed it at the time when English viols, viol players and viol repertoire were considered the European leaders. He wrote about some differences between English and French viols, and if there was a difference in how notes were produced, it would surely have been mentioned. In his Book 1 Proposition 4, he wrote: 'Now the percussive sound made by the viols has still something rough, which participates a little in sharpness and hardness, and which is not refined enough for the delicate ear, unless there be some distance from the place of the percussion to the ear, which makes the sound softer and strips it of what is harder and more earthy.' In Book 3 Proposition 1, he wrote that the spinet 'blends particularly with the viols which have a percussive and resonant sound like the spinet'.

In Book 4 Proposition 5, Mersenne wrote that the viol 'imitates the voice in all its modulations'. John Hsu (in his paper 'The use of the bow in French solo viol playing of the 17th and 18th centuries', *Early music* (October 1978), pp.526-9) demonstrated that this 'plucking with the bow' primary kind of sound production persisted throughout the viol's popularity, and wrote that 'the basic bow stroke always enunciates a word beginning with a consonant'. That stroke was called the *coup de poignet*, meaning 'blow with the wrist'.

In England, it is clear that viols and voices were rather interchangeable in performance. The traditions of note production on both voices and viols were apparently quite different then than they are now.
Stress and Equilibrium Moisture Content in Gut and Wood

The structural integrity of animal and plants tissues is provided by the ubiquitous biopolymers collagen in animals and cellulose in plants. The gut used for strings is almost pure collagen. The wood used in instruments is about half cellulose and about a quarter hemicellulose, a branched polymer similar to collagen and about a quarter lignin. In their original natural states, the biopolymers of gut and wood exist in an environment wet with water, so the polymers that absorb water, which are collagen and hemicellulose, are fully swollen with water. When we use these materials, they are much dryer than in their natural states, and the degree to which they are swollen depends on the relative humidity of the surrounding air. It is possible to produce tables that give the % moisture content in equilibrium with each % relative humidity. The relative humidity is the moisture content of the air as a % of the maximum moisture content that air at that temperature can hold. The maximum moisture content of air increases with higher temperature and decreases with lower temperature.

Gut: A tuned-up gut string that is stable (i.e. its inelastic stretching rate is negligibly small) in a particular atmospheric relative humidity will soon rise in pitch when the relative humidity is increased. The increase in relative humidity can be from a change to more moist weather or lower temperature at the same place, or from moving the instrument to a different place where the air is more moist or at a lower temperature. The reason for this is that the gut swells with increased moisture content. Since it is made of twisted fibres, the increased diameter of the string increases the average helical path of the individual fibres, stretching them further. Since the ends are fixed, stretching the fibres increases the tension, which raises the pitch. The increased moisture content also adds weight to the string, which lowers the pitch. If the increase in moisture content is small, the effect of the increase in tension is greater than the effect of the increase in weight, and the pitch rises. If the moisture content gets much greater, the effect of the added weight of the water predominates, and the pitch falls.

When a string is thicker or has higher twist, the relative swelling would have the same proportion to the relative elongation of the fibres, leading us to expect that the change in pitch with changing moisture content would be independent of these factors. This would be true if the equilibrium moisture content depended only on the relative humidity, but there is evidence suggesting that it also is dependent on the stress in the string.

If one detunes the strings of a bowed instrument to take the bridge off to do some work on it, then after the work is done and the bridge is replaced, it is usual to find that the strings are shorter than they were before, requiring more peg loosening to get the bridge back under them. This phenomenon needs explaining. It is possible that the release of the tension might allow a slow reorganisation of the molecules in each fibre that reverses the changes in organisation involved in the initial stretching of the string. Another possibility is that when a string is stressed by being put under tension, it can absorb less water, and when the tension was released, the gut contracts as it absorbs the extra water that it now can hold. This says that the equilibrium moisture content of gut depends on the stress in the string as well as on the relative humidity. It is likely that both processes are happening, and in the reverse situation of first tuning up a string, some of what appears to be inelastic stretching involves the stretching associated with loss of moisture. Studying the relative amounts of these effects would be a good project for an undergraduate mechanics laboratory.

The second effect mentioned above would also explain the observation that thicker gut strings tend more than thinner ones to go out of tune when the humidity changes. The stress in the gut is the tensile divided by the cross-sectional area, and represents the distorting force on each little bit of the gut caused by the tension. Strings at lower pitches are thicker and have either the same or lower tension, so the stress in them is lower, allowing more absorbed moisture for each bit of gut, and with more moisture to go in and out when humidity changes, greater changes in pitch would result.

Another example of this effect concerns buzzing from loose windings on an old-style wound string like we make. It is much more likely to occur when the string had been taken out of its packet and kept as a spare for some time before being used than when it is mounted on an instrument directly after being taken out of its sealed packet. The loose windings result when the gut core swells with high humidity and stretches the winding, and then lowered humidity returns the core to its original thickness. When the string is under tension, it will not swell that much.
Wood: Stress also changes the equilibrium between the moisture content in wood and the relative humidity. Normally, when the humidity rises, wood expands as it absorbs moisture from the air up to the new equilibrium amount. The expansion is very little in the grain direction (the vertical direction in the standing tree trunk), and is almost all in directions perpendicular to the grain. The expansion is about twice as much in the tangential direction (along the circumference of the trunk) as in the radial direction (from the centre of the trunk outwards). When two pieces of wood with different orientations of these three directions are glued together at one humidity, and then the humidity increases, they are inhibited from expanding as they normally would. They expand a compromise amount, with the nature of the compromise governed by the relative elasticities of the two pieces in each direction along the glued surface. The stresses in each are equal and opposite, and if the glue is not strong enough, they will pop the pieces apart.

Of concern here is what happens to the moisture content of the stressed wood. The answer appears to be that the wood will absorb no more water than it can expand with. One piece of evidence supporting this is that cracks in old lute soundboards often stop where cross-bars have been glued under them. The cracks are due to cycling of moisture content that causes degradation of the wood hemicellulose, which results in contraction. Where glued to the crossbars, there is no contraction because there was no cycling in moisture content since the grain direction in the cross bars prevented movement in the soundboard wood from weather changes. Another piece of evidence is that the weight of plywood varies much less with relative humidity changes than the weight of normal wood.

When a change in the relative humidity of the air changes the equilibrium water content of the wood, the change in water content starts on the surface in contact with the air and propagates inwards. The gradient in water content associated with this propagation causes strain in the wood, and the resulting stress is probably what helps the degradation of the hemicellulose that is observed in old wood. Water absorbs acoustic vibration of wood, and the moisture content needs to be low for good sounding soundboards. After an initial drying of newly felled wood, it is traditional to ‘cure’ the wood for about 5 years before it is used in instruments, and it is traditional practice to do at least some of the ‘curing’ outdoors under cover, exposing it to cycling in moisture content due to the weather. This cycling degrades hemicellulose, and the resulting further reduction in the water content (reducing sound absorption) is probably the reason behind the tradition.

The Hunt & Balsan experiment (see Comm. 1471) demonstrated a small change in the equilibrium moisture content of wood at a constant high relative humidity as a result of the strain produced by vibration. At more normal lower relative humidities, the change was too small to measure. They thought that they were addressing the problem of sound improvement of new violins by playing them in. A more realistic model for that improvement involves sound energy absorption by creep (inelastic deformation) which uses that energy to speed up the creep. But that effect is unrelated to the relationship between the equilibrium moisture content and stress being discussed here.