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H. C. COLLES, Esq., M.A.,

IN THE CHAIR.

THE HERITAGE OF GREECE IN MUSIC.

BY WILFRID PERRETT, PH.D.,

Reader in German in the University of London.

THE only professor of Greek I have ever known who was also a musician always refused on principle to give me any help with a stiff passage from a Greek author on music. His reply was always the same: "Put that stuff away. Nobody has ever made head or tail of Greek music, and nobody ever will. That way madness lies." It was in vain I promised to become a *harmless* lunatic. I respect his opinion, and my own. Among what looks like a heap of lumber two things have taken my fancy and engaged my attention at intervals during a lengthy period consisting mainly of interruptions. One thing is the way the Pythagoreans had of defining musical intervals by ratios. Their methods can be much improved and simplified by means of two tools of British invention: logarithms and tuning-forks. The other thing is the tradition, not altogether vague, of "the genuine and beautiful Greek music," the lost enharmonic genus. These two in combination promise something of great value for the future of music. I am not going back to what we have already inherited from Greece, to Boethius and medieval music or even to Zarlino and the renaissance. That tale has been told. I am not convinced that there is anything in the heritage of Greece in music now worth troubling about beyond the two things mentioned. This without prejudice to what others may find in that same lumber-room. That a phonetician should meddle with music ought not to occasion surprise. Many of our leading phoneticians have done so:—Wallis, Holder, Thomas Young, Willis, Wheatstone, Ellis. It is in the English tradition. So much by way of apology.

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This paper is intended as a supplement to the work of A. J. Ellis. It may be news to some of those present that

his tonometrical investigations into the *Musical Scales of Various Nations*, in collaboration with A. J. Hipkins ("the two A.J.'s," a wonderfully strong partnership lasting fourteen years, 1876-1890), published in 1885, is translated into German in Vol. I of *Sammelbände für Musikwissenschaft*, 1922, and is now regarded as a classic in the German schools of musicology. In every German university there is now a chair of Musikwissenschaft (musicology), a luxury which we in England apparently cannot afford. Ellis's system of logarithmic cents, a linear measure for musical intervals as handy as a two-foot rule, is in constant use wherever these problems are effectively studied.

The application of Ellis's cents enables us to prove, once for all, that Aristoxenos did *not* divide the octave into twelve equal semitones. His theory divides the just fourth into 30 equal parts, and certainly postulates equal semitones. But twelve of his equal semitones do not make an octave. They amount to 1,195.308c. instead of 1,200c. Now the octave is the one and only interval on the piano, organ, etc., that must be tuned true to its ratio, 1 : 2. With one exception the octave tested by Ellis on seven keyboard instruments in equal temperament was not more than one cent sharp or flat. The error of 1c., if not allowed to accumulate, may be neglected. It is not perceptible melodically to the finest ear under the most favourable conditions. But what would you say of a tuner who left every octave nearer five than four cents flat?

If we wish to find an anticipation of equal temperament we must turn, not to Greece, but to China, where about 1595 Prince Tsai-yu somehow contrived to work out the ratio of our equal semitone, $1 : \sqrt[12]{2}$, with altogether excessive exactitude. How he did this is not clear. He does not show the working. But he got the answer all right, very much so : a fraction which may be written 1.059,463,094 etc. to fifteen more places of decimals (Maurice Courant in *Lavignac*, I, 91).

As a mathematician, Aristoxenos was not a success. His one attempt at exact measurement with the monochord (ed. Macran, 56, 57), where he tried to prove that a just fourth is made up of two major tones and a half, made him the laughing-stock of the more narrow-minded of the Pythagoreans, and gave rise to the bad joke about hemitonos, a semitone, and hemionos, a semi-ass, meaning a mule. It is a pity, because on the æsthetic side he is unsurpassed. His

conception of good singing—no “wobble,” no singing off pitch, no slurring or scooping, as little vibrato as possible—is admirable in its austerity. Helmholtz and Ellis call the ditone, made up of two major tones (64 : 81, 408c.) the Pythagorean major third. It should, surely, be called the Aristoxenian major third; Aristoxenos measures off the two major tones before our eyes.

As to Hipkins: after some forty years the assertion that piano-makers cause the hammer to strike the string at a point which eliminates the 7th harmonic, repeated as scientific fact by innumerable writers, is degraded to a false hypothesis in Vol. VIII of Geiger & Scheel, *Handbuch der Physik*, 1927, p. 187. Professor Kalähne should have given the reference to two papers in the Proceedings of the Royal Society, 1885, in which Hipkins, who was Broadwood's expert, showed that the observations of Helmholtz on this point were erroneous in every respect. About twenty years ago I used to listen to a bass string in every good piano I could come across. The 7th harmonic is one of the most prominent. It can *invariably* be detected by the beats which it makes with the minor seventh three octaves above.

Among the various nations considered by Ellis, the ancient Greeks come badly off. Ellis had no first-hand knowledge of the Greek authors on music. He placed all his confidence in the much over-rated authority of Helmholtz. It is as Hipkins admitted in 1902: they had both of them been content to follow the too easy tabulation of Helmholtz. After Ellis's death in 1890 Hipkins devoted all his scanty leisure to the study of Greek music, and was certainly well away when he found it essential to “appreciate septimal intervals—the ratios 7 : 8, 6 : 7, and also 4 : 7—and to regard scales rather in *descending* than in *ascending* order.” I find, too, among his MS. notes that he had booked the diesis of Archytas, 28 : 27, 63c., perhaps the most striking omission in Ellis's table of over 150 intervals less than an octave. This interval has been repeatedly singled out for condemnation as irrational, without any attempt whatever at experimental proof. For example, on p. 153 of Weil & Reinach's quite indispensable edition of Plutarch *De Musica* we are told that the intervals of the tense diatonic tetrachord of Archytas and of the lax diatonic recorded by Ptolemy are *tout à fait irrationnels*. This instrument, the Olympion, proves the contrary. Ptolemy accepted the diesis of Archytas only as a chromatic semitone. According to him it was too small for

the diatonic genus and too big for the enharmonic. Archytas himself, however, employed it both as a semitone *and as a quarter-tone*, and this throws a flood-light on the function of small intervals and small differences between intervals. When you cross a stream on stepping-stones, there may be long steps and short steps, but you do not trouble about the exact size of the steps; the essential thing is to step from one firm foothold to another.

Archytas of Tarentum was a contemporary and friend of Plato, whose life he once saved. He was a distinguished statesman, general, inventor and engineer. The poet Horace in one of his most moving odes (I, 28) recalls Archytas as the great mathematician who could measure land and sea, and set a number to the seeming infinity of grains of sand. Yet all his attainments and achievements were powerless against death :

*nec quicquam tibi prodest
Aërias tentasse domos, animoque rotundum
Percurrisse polum, morituro.*

But numbers cannot fail. When Archytas wrote down the ratios of the enharmonic tetrachord in the Dorian mode at Phrygian pitch (G down to D), he too wrought a monument more durable than bronze.

Archytas has had to wait twenty-two centuries for his vindication as a musician. The harmony latent in his ratios was revealed for the first time at the Royal Institution last November. I shall now ask you to listen to the supposedly irrational interval 28 : 27. . . . In that passage I have brought in two tetrachords containing the diesis of Archytas, a chromatic, and a lax diatonic. I will now sound four such tetrachords melodically, two of them authentic, two inferred, in this order : tense diatonic, lax diatonic, chromatic, enharmonic ; and will harmonise the last one. . . .

What Helmholtz and Ellis call the Old Chromatic either was or became unknown in Ancient Greece. Our chromatic semitone, 24 : 25, 70c. was first introduced by Didymus, a Pythagorean living in Rome in the time of Nero. It was rejected by Ptolemy as quite unsingable, quite out of tune. Helmholtz, through some strange confusion, ascribed the chromatic tetrachord of Didymus to Eratosthenes, 250 years earlier. How such a blunder can have remained unchallenged by two generations of musicians is beyond my comprehension. We know nothing of the tetrachords of Didymus and Eratosthenes except what Ptolemy the astronomer tells us.

Writing in Alexandria before the destruction of the library, he had access to many books now lost. There was no good edition of his invaluable work on *Harmonics* until that of Wallis, 1682. There has been no edition at all of Ptolemy's *Harmonics* between that of Wallis, 1699, and the recent one by a Swedish scholar, Ingemar Düring, 1930.

Our chromatic semitone, rejected by Ptolemy, is of course precisely the interval by which in just intonation we pass from the minor third to the major third, or from the minor sixth to the major sixth. It is the very foundation of tertian harmony, the major-minor system in which all our classical music is composed. It is the use of this interval that developed our sense of tonality, something which is only rudimentary in the Greek scales, and decided our choice in favour of the Lydian mode for our diatonic scale in preference to the national Greek Dorian mode (descending from E to E) or any other mode. This does not mean that the Greeks had not the major triad and the minor triad. On the contrary, among those "most ancient" enharmonic scales given by Aristides Quintilianus (*Meibom*, p. 22) there is the Iastian with the major triad F, A, C on successive notes, and four of the seven notes of the Syntonolydian enharmonic are F, A, C, E in that order. But they do not appear to have had, in any scale, major and minor triads from the same tonic. By rejecting the 24 : 25 semitone Ptolemy condemned the whole major-minor system which was finally, on the *clavichord* of Johann Sebastian Bach, to be established on twelve key-notes to the octave. We may say, without doing Ptolemy any injustice, that he did not know what he was talking about.

On the other hand, Pole in his *Philosophy of Music*, p. 244, says that if voices were singing the full major chord, the substitution of the harmonic seventh for the dominant seventh "would not do at all; it would be unsingable," whereas Ellis maintained—what is self-evident with properly tuned reeds—that the harmonic seventh is the sole justification for the far harsher chord of the dominant seventh. If Ptolemy and Pole were both right, it is a wonder that we can sing anything beyond the plain diatonic. But they were both wrong. Just as Aristoxenos in his theorem became entangled in the Greek tempered scale with ditone and limma, so Pole was unable to free himself from the ambiguities of equal temperament, which substitutes *e.g.* in the key of C, one compromise B^b, 1,000c., for three distinct notes, 'k^b, 4 : 7, 969c., k^b, 9 : 16, 996c., and B^b, 5 : 9, 1,018c., all three of

which are harmonically related to the key-note. Pole's table on p. 222 showing the same degree of roughness for 5 : 6, 5 : 9, and the tritone, the diabolic interval, 32 : 45, proves that he too did not *know* what he was talking about. Pole can never have had an opportunity to submit this estimate to the test of exact experiment. If there is not too much noise, it is possible to attempt an analysis of the repulsive combination *Mi contra Fa*, best taken for the purpose in the twice-accented octave. The reeds *f''*, *b''* sounding together produce two Tartini tones, making an interval somewhere between the fourth and the fifth. The ear is not able to define them much more closely than that. They are irrational. But a simple calculation shows that the full discord is as 13 : 19 : 32 : 45, and a reference to Ellis's Table and a little patience give 657c. as the equivalent of 13 : 19. So now we know that F sustained or remembered against B produces two more notes, heard or under-heard, which together make an impossible Fifth, 45c. or a quarter of a minor tone flat. Dr. Burney knew what Shakespeare meant by *Fa*,—*Sol*, *La*, *Me* (this is the correct reading of the First Folio, with a dash after *Fa*) in *King Lear*, I, ii, 129. Chappell did not know. Wright and subsequent editors do not know.

Now is it creditable that Palestrina intended his singers to intone F against B (G, D) in the example quoted by Pole, p. 189? I simply cannot believe it. This *seventh* of Palestrina and Monteverde is not, as Pole would have it, the dominant seventh, 9 : 16. It is the harmonic seventh, 4 : 7. The singer would instinctively flatten the note written F (*musica ficta*) by a septimal comma, just as Olympos flattened F on his Phrygian flute (he could not have sharpened B, because the four invariable notes in the Dorian mode were fixed by the ratio, in Aristotle and everywhere else as far as I know, 6 : 8 : 9 : 12 for E, A, B, E).

Let me now explain that this experimental harmonium which I have called the Olympion gives, firstly, the diatonic scales of C major and C minor in as nearly just intonation as the conditions allow. With two variables, pressure and temperature, it is and always has been impossible to make perfect tuning permanent. With the thermostat, the electric fans and the delicate anemometers of our unsurpassed organ-builders (see Reginald Whitworth, *The Electric Organ*, 1930), it is by no means impossible. The grand organ of the future will be played under laboratory conditions. With these two scales is combined the minor scale in the key of septimal B $\flat$, that is, the harmonic seventh of C, which was

the Mese or middle note of the new diatonic found by Olympos the Phrygian flute player of about 650 B.C., to whom the discovery of the enharmonic genus is ascribed. Two more notes, giving the major third and major sixth from the septimal key-note, make up a total of twenty notes to the octave from C to C inclusive. Thus the combined scale embodies the advice given by Dr. Wallis to the Rev. Thos. Salmon, rector of Mepsal, in 1688.

40 Dr. Wallis's Remarks on the

Sixth.) In like manner, if I would, from C, rise a Fourth to F, at two near-equal steps, (as when we rise an Eighth by a Fifth and Fourth; or a Fifth, by greater and lesser Third;) that is, if I would divide the Proportion of 3 to 4, or 6 to 8, into two near-equals; those are to be 6 to 7, and 7 to 8: And therefore CD* as 6 to 7, and D* F as 7 to 8, (whatever chance thereby to be the division of DE.) And the like for other cases. So that for instance, the same D* or F*, as to different purposes, shall signify differently. And such Arts we must make use of, if we would revive the *Greeks Chromatick* and *Enarmonick* Musick. But the Speculation is too nice for most of our present Practisers.

It has Wallis's harmonic division of the fourths C to F, D to G, Eb to Ab, E to A, G to C, Bb to Eb, and B to E. But F to Bb and A to D are acute fourths (20 : 27) a comma too wide, and cannot be treated in this way. This is the secret of the lost enharmonic which Tartini the violinist discovered in 1754, that it did not shift the comma or temper the natural intervals of the diatonic scale. It kept the comma in its place and supplemented tertian by septimal harmony. Please do not misunderstand me at this point. There is no evidence whatever that the Greeks ever employed more than two sustained notes at the same time. The only instrument that would do even this was the double pipe or Phrygian flute. We are at liberty to assume, if we wish, that they played arpeggios while a deeper note was sounding. If, as we may gather from Giraldus Cambrensis, the Welsh harpers in the twelfth century knew how to do this (*sub obtuso grossioris chordae sonitu, gracilium tinnitus licentius ludunt*, etc.), why not the ancient Greeks? The fact that Plato refused to admit into his ideal Republic "the artificers of lyres . . . with complex scales, or of any other many-stringed and curiously-harmonised instruments" shows that such instruments and instrument-makers were not unheard of.

And as Thomas Young remarked, an arpeggio is virtually an accord.

There is ample evidence for two notes. Plutarch quotes examples of two notes sounding together on the Phrygian flute, making intervals of the fifth, fourth, major third, minor third, and major tone, in all examples but one the accompaniment (*crusis*) being above the melody (*melos*). *But* to some persons two sustained notes may mean either three notes or four notes. Tartini was one of these, Joachim was another, the late Sir Thomas Wrightson was another. It is on record that all three employed septimal intervals in their double-stopping. Olympos, 2,400 years before Tartini, was in the best possible position to hear Tartini tones. Ellis pointed out long ago that the best way to hear them is to play on two flageolets at once. It is then impossible for the performer to escape them unless his ear is strangely obtuse. I myself was puzzled and disgusted by grossly discordant Tartini tones from a toy dulcimer at the age of six or seven—before I had learned to read. My friend R.S., at the age of *two years and three days*, showed me a novel and ingenious way of cutting out the fierce resultant tones from a gramophone in a small room. He flapped the auricle over the meatus, and holding it down airtight with two fingers and a thumb, demanded more “mooky,” which rhymed with bookie and meant music, for three-quarters of an hour. I am still puzzled by the accepted theory of resultant tones, which no doubt corresponds to something in abstract physical science, but does not correspond to or explain what the ear can perceive. Has anyone yet heard a summation tone? I never have, though goodness knows I’ve had chances enough in the past three years trying to make the squealing overtones of these brass reeds scream in concord. Sir Thomas Wrightson told me he had never heard summation tones, though his theory of the internal ear accounts for them, and they have accounted for his theory (but his *dead beat* hypothesis remains, and awaits a better superstructure). I think we shall return some day to the beat-tone hypothesis of Serre (1753), accepted by Lagrange and developed by Thomas Young, who was the first to show, about 1800, that it is possible to hear two Tartini tones at the same time. Ellis and Pole did not know this, and it detracts somewhat from the value of their work. In tuning a concord of reeds one should judge finally, not negatively by the absence of beats, but positively by the fullness and roundness of the lovely undertones; and if the concord 5 : 6 : 7 : 8 : 10 from middle

C finally sounds less smooth than $4 : 5 : 6 : 8$, there is something wrong. I never realised how few persons are able to detect these undertones (Tartini tones) until I tried to demonstrate the enharmonic system of Olympos before the Philological Society in 1928 by means of an octave of twenty tuning-forks, when I found to my dismay that in most cases the demonstration was a complete failure. Hence the necessity for the present instrument, to bring out the latent harmony.

For example, these two tuning-forks give Tartini's substitute for the tritone $32 : 45$ in the ascending scale from C. Their ratio is $5 : 7$, which is the inversion of $10 : 7$, found, as I infer, by Olympos as a substitute for the tritone down from B to F ($45 : 32$) in the Greek descending scale from E. (Some years ago I asked the Greek Metropolitan Germanos to sing me the diatonic scale. He most obligingly responded at once with a descending scale: tone, tone, semitone, tone, tone, tone, semitone. That is the ancient Greek national scale in the Dorian mode and diatonic genus.) The resultant tones from these two forks may be inaudible. They form a just Fifth, $A^b - E^b$. On the harmonium the accord $2 : 3 : 5 : 7$ with middle C as 5 should be heard as a perfectly smooth concord. This is the true form of the accord known as the German Sixth. According to Helmholtz (p. 228) "the scales of modern music cannot possibly accept tones determined by the number 7," a truly colossal blunder. As an example of the irony of things, this would be hard to beat: that after all his labours in the cause of what he conceived to be just intonation, Helmholtz denied the ideal existence of the German Sixth.

The first question to ask of any scheme for just intonation is, does it contain the interval $5 : 7$ from each key-note? If not, it is useless. Another indispensable interval is $10 : 7$ down from the major seventh in each key. This slide shows a scheme with 61 notes to the octave published last year. Further experiment has convinced me that this scheme is also incomplete. With each substantive key-note we must have the 17th harmonic found by Ellis to give the true form of the accords of the minor seventh and ninth, $(8) : 10 : 12 : 14 : 17$. Even then we should be well within the limit of Bosanquet's symmetrical keyboard (*Slide*) in the Science Museum at South Kensington, with 84 digitals to the octave, said to be easier to play than the piano, because with no matter what change of key the fingering remains the same. But the arrangement would have to be different.

I am sorry I cannot illustrate septendecimal harmony on this instrument as it is now tuned. It does not go beyond septimal harmony. I have been asked if I can play a tune on it. It is rather difficult to find one, because while it has three flats, it has *no sharps*, and it is quite impossible to play D with F or A, or F with B or B $\flat$, but I will now ask you to listen to a *septimal* version of Tallis's Canon, first in F, then in C, with some "lost chords." . . .

The upper register of reeds has a distressing penny-trumpet quality of tone, and I have never yet succeeded in getting it into satisfactory tune. Nobody in England now makes harmonium reeds. It is one of our minor industries that have quite gone under. (Organ-reeds are a different proposition.) And since the death of Mr. William Humphreys I know of no one who has the knack of voicing harmonium reeds. You must have noticed the unevenness here. A maker of steel concertina reeds, which I don't want—they seem to me still more cutting and blatant than brass—tells me that my brass reeds are very poor specimens. That may be; but if nobody in the country can provide what you need, you have to put up with what you can get from abroad. While on the subject of reeds may I add a note to pp. 120, 125 of my book, which may be misleading. *Invar* has no co-efficient of expansion, but its elasticity varies with temperature. *Elinvar* on the contrary has a constant modulus of elasticity over an ample range of temperature, and it would be worth while to experiment with it. Such specimens of these alloys as I have seen, *as yet*, are altogether too inelastic. This strip, you see, when I bend it, stays bent. [Mr. R. W. Western, who was present when this paper was read, very kindly informs me, on the authority of Professor Boys, that admirable watch-springs have been made of elinvar, which should therefore be suitable for reeds.]

With the harmonically divided fourths we get closer harmony than is possible on our keyboard instruments. Listen to 6 : 7 : 8, 5 : 6 : 7, 7 : 8 : 10, etc., in this sequence . . . ; 9 : 10 : 14 in this one These are not *discords*. The melodic interval E $\flat$ to 'F, 32 : 35, 155c. may look irrational on paper, but did not sound so as I have just played it in the series B $\flat$ 6 : 7 : 8, B 5 : 6 : 7, etc. If it is true that "we have no experience of septimal harmony," that is not the fault of A. J. Ellis, but the confession implies that we cannot appreciate fine chamber-music when we hear it. Professor Max F. Meyer, who, by the way, was first in the field with an *equal* quarter-tone pianoforte (*Slide*) in 1902, wrote to me

from Columbia, Mo., in 1930: "It is very agreeable news to me that someone else, too, has the conviction that the intervals whose terms include 7, play, and have played, a larger rôle in music than is usually imagined."

Septimal intervals are quite possible on a perfect instrument as defined by Dr. Robert Smith, 1769: "By a perfect instrument I mean a voice, violin, violoncello, etc., with which a good musician can perfectly express any sound which his ear requires."

A well-known violinist, a neighbour of mine, who is also a good musician in Dr. Smith's sense when he wants to be or is permitted to be, having ten minutes to spare one day, consented to be used as a *Versuchstier*. I asked him to repeat the melody of . . . in which the harmonic seventh of Ab has to change to a note which is not on this harmonium, namely, the leading note to G. He performed this feat perfectly and without hesitation, not by shifting the finger on the string, but by "pressing a little harder." Thus he showed himself able to appreciate and render, under harmonic guidance, the difference between 583c. and 590c. Why should he not, being given C and B by the reeds? It was merely a case of raising the "Gb," the Tartini interval from C, to "F#," the fifth from B. The exact difference is in vibrations 1.62, and in cents 7.712, or one twenty-sixth part of a tone on the piano, but of course he did not know this. Why should he? It seems to follow that sharps and flats for chamber music are like the medieval neumes: unless you know what they stand for, you cannot tell.

If I sound this mistuned fifth (695 instead of 702c.) on the harmonium . . . you cannot fail to hear the loud knocking of the lowest series of beats. They come at the rate of thirteen in four seconds. Beats are noise, and if the energy that should go into the production of tone is wasted in producing noise, the tonal quality of the whole instrument is impaired. This interval of approximately 7c., making all the difference between happiness and misery, recurs so frequently that I decided to see what would happen, on paper, if the octave were divided into 171 equal parts. I have worked it out, and find that this new cycle contains all the intervals of quintal, tertian, septimal, and septendecimal harmony to within 1c. The claim may therefore be made that the cycle of 171 represents the perfect musical scale.

Slide. Thomas Young on Tartini tones. The handwriting on a bookmark found at this page is Faraday's. Young's clue being followed up leads to a chromatic scale with one

extra note, between A, 884c. and B $\flat$, 1,018c. I have dealt with this in Chapter VI, but would like to add that the alternative route, from A, 884c. over kB $\flat$, 996c. is much easier to find than I thought. All that is necessary is to have F as well as C in mind. The division of the 134c. semitone was also found by Tartini, and occurs frequently in the *Orestes* fragment. Listen to this chromatic scale. Where does the extra note come in? . . . first melodically, then . . . in septimal harmony. [What the unhappy reader is to make of all these lacunæ I really do not know. Hamlet without the Prince of Denmark is beaten to a standstill. Some means of appealing directly to the ear must be found. A gramophone record possibly.]

Slide. The passage found only in Plutarch in which Aristoxenos relates how Olympos made his discovery. This third clue presented itself first. About the meaning of ἀναλογία I am, philologically, still very sore; so will pass on, with the recommendation to look up the word in the larger Liddell & Scott.

Slide. The various solutions proposed for the enharmonic tetrachord, from 350 B.C. to 1896 A.D. Those of Archytas, Serre, and Tartini (2) are correct solutions. By rejecting the just major third of Archytas, Torr put himself out of the running.

Listen, please, to this descending scale: major third, diatonic semitone, major tone, major third, diatonic semitone, major third, diatonic semitone, major tone, starting from 'F' (actual pitch, about D above middle C). It is the vocal enharmonic in which Olympos composed his melodies, loved and lost. He left the division of the semitone to the instrumentalists. It has occurred to a number of musicians to add the harmonic seventh to the common accord; but Olympos apparently had the unique idea of adding the common accord, in arpeggio of course, to the harmonic seventh. The Olympion illustrates this, but with accords, not arpeggios. It was built to illustrate this . . . But it will not do so really well unless the temperature is just about 62° F. [It is now, most unfortunately, 72° F!]

We come at last to the only known specimen of Greek enharmonic music, a scrap of papyrus about 3 inches by 3½, found in Egypt and made known in 1894 by K. Wessely. It is a fragment of a chorus, sung by men in unison, from the tragedy of *Orestes*, written and composed by Euripides, 405 B.C. *Slide.* This is Torr's restoration of the fragment, from the Introductory Volume of the Oxford History of

Music. The vocal notes are written over the text, a few instrumental notes in line with the text. Two of the instrumental signs occur nowhere else, but contrary to what has been stated and repeated, the vocal notes without exception and two instrumental notes are to be found in what Alypius called the Hypo-Lydian scales, in Macran's *Aristoxenus*, p. 56. This fragment has been much discussed, but to little purpose. Scholars are agreed that it cannot offer anything of value to modern music. They hold that its quarter-tones are insusceptible of harmony, and would sound utterly barbarous to modern ears.

I have time to discuss only one point. The first vocal sign in l. 9, if it is what it looks like, a sprawling W, or M upside down, means B in the bass, and Euripides had done a most astonishing thing, though Torr says not a word about it. No rule could be more clearly stated than this by Aristoxenos (54), "Whatever be the genus, from whatever note one starts, if the melody moves in continuous progression either upwards or downwards, the fourth note in order from any note must form with it the concord of the Fourth." Here the four notes in continuous progression upwards from B to B $\flat$ cover an octave all but a chromatic semitone, and Euripides has broken the rule a century before it was formulated by Aristoxenos.

Slide. There is no other facsimile than that of Wessely. I have permission from the Austrian State Press to reprint it.

Slide. Here we have Torr and Wessely side by side. Where is the notch making three angles at the base of a W? Let us try the alignment.

Slide. A straight line drawn under the following three vocal notes, Sigma, Rho, Pi, shows that the apparent base of the first of the four is, in the original, 2mm. out of alignment. By producing the two sides of the disputed letter to a point on the straight line we get an inverse Alpha which may be compared with A in the text, as in *materos*, l. 2. That is the required letter. The various guesses, Omega, Phi, Lambda Delta, Mu, are incorrect. Inverse Alpha in the relevant enharmonic scale (Macran, p. 56) means F. But F to B $\flat$ is not "the concord of a Fourth." It is the acute fourth, 20 : 27. Aristoxenos would find a difficulty here, perhaps. But for us it has been removed by the genius of Tartini. The two semitones which Euripides in this fragment (unlike Olympos) required his *singers* to divide, A—B $\flat$, 25 : 27, 134c., and E—F, 15 : 16, 112c., are precisely the two which

Tartini divided on his violin by the harmonic sevenths of C and G. Tartini gives the ratios of his harmonised acute fourth, A—D, 20:27, so there is no possibility of a misunderstanding. He found the effect of his double-stopping extremely pleasing.

This last slide is a transcription of the vocal notes in the fragment, the triangular notehead denoting a harmonic seventh. In the harmonisation which I shall now play, all the decipherable notes are employed as they come, with some *remplissage* to integrate the disjointed *melos*, in the key of F . . .

As a last example, *God rest you Merry, Gentlemen*, passing into the Dorian diatonic scale. As you hear, we must use 'F to descend from the second of the scale, and this proves that from E to D in the old diatonic from which Olympos took his departure was 10:9 (Ptolemy) as in our C major, not 9:8 (Didymus).

DISCUSSION.

THE CHAIRMAN invited Miss Schlesinger to open the discussion.

MISS SCHLESINGER: I wish you had asked someone else to speak first. I would like first of all to thank Dr. Perrett for his most interesting exposition of the whole subject. He has touched upon so many points of deep interest to me in Greek music, that I find it difficult to single out any one for special reference and to say anything lucid in a very short time on this subject. But I think that we understand the title quite differently. I do not know whether I am right in assuming that the "Heritage of Greece in Music" should be taken as suggestive of what can be made out of the scale of Olympos for future use, or whether it signifies what it means to me, *viz.*, all that Greece has left us: the foundations of our theory of music and of the science of acoustics, which have been further developed through the Middle Ages, and more especially the Keys and the Modes still surviving now in folk-music.

But one point I would like to make which I consider of vital importance. In all these discussions with regard to ancient music, more especially Greek, before any theory of this kind can be accepted, it seems to me that it must be demonstrated that the two instruments which were in use in Greece, *viz.*, the *Kithara* and the *Aulos*, were capable of reproducing the scale specified in the theories; that it should be possible, for instance, on an *Aulos* to play Dr. Perrett's

interpretation of the scale of Olympos, the Phrygian Piper.

According to my experience and to available evidence, that is absolutely impossible on any primitive reed-blown instrument. The *Aulos* was a reep-pipe played either with a primitive oboe mouthpiece or a primitive clarinet mouthpiece, and the part of the pipe in which the finger-holes are bored is only a resonator. All resonators respond only in obedience to the law of proportion and in accordance with what has been initiated through the mouthpiece. To suggest that a sequence such as this highly sophisticated scale of Olympos could be put on an *Aulos* by a primitive pipe-maker would be a very difficult proposition to substantiate.

The original resonator is converted into several, of different lengths, by the opening of the finger-holes, and the mouthpiece must be capable of adapting its vibrations to each of these proportional lengths. This is accomplished instinctively by means of a series of proportional processes in which piper and mouthpiece both take part. The suggested method of bringing the scale into being by cyclic fifths and sevenths cannot be carried out on an *Aulos*. Even if the resulting scale be referred to the *Kithara*, there would be cogent reasons against the hypothesis, the least of which would be the cardinal error of its attribution to the great Phrygian piper.

So that when I have said this, I have not answered any special point. I have only indicated the difficulties, and I think I will leave it to others to bring forward points which will probably be of greater interest to members of the Musical Association, being of a more musical and less evolutionary nature.

Mr. WESTON: Did I understand Dr. Perrett to say that the *Orestes* fragment was the *only* fragment? He did not mean that, did he?

Dr. PERRETT: It is absolutely the only specimen there is of the lost enharmonic genus which Aristoxenus valued very much above the other two genera.

Mr. WESTON: In Archytas you referred to a Dorian method of pitch definition. How far do you go in that very interesting question? Did you not refer to the Dorian method of definite pitch?

Dr. PERRETT: The word *tonos* was already a source of confusion to the Greek writers themselves. Even in Greek it had three distinct meanings. *Tonos* can mean "mode" and it can also mean "pitch." The pitch of this Fragment, according to Emmanuel, would be Hypolydian, because the

Greek chorus, consisting of men, were not asked to sing above the note F, that is our D above middle C, so that the notes to be sung were always well within the compass of the baritones and basses as well as any tenors who happened to be there. Hence this Fragment would be in the Hypolydian pitch.

If you turn to Macran's *Aristoxenus*, page 56, you will find, contrary to what has been said by many people, that all the vocal notes without exception are there, and the two decipherable instrumental notes are also there. Macran gives the approximate values to these notes, and by defining the relative pitch as accurately as possible my instrument gives the true values, or would have done, but that the temperature has gone up to 72 degrees, whereas this instrument is tuned for 62 degrees Fahrenheit. Does that answer your question?

Mr. WESTON: Yes, practically. I was aware of that fact, but I wondered at your making a statement which seemed to imply that there was a distinct conception of pitch as we view it in these days.

Dr. PERRETT: No, it is simply by working out the intervals given by the ratios of the Pythagoreans, chief of whom was Archytas. The absolute pitch of the Greek "middle note," our A, is supposed to have been about a minor third below the A of this instrument, which is that of the French "diapason normal," 435.4 v.d. at temperature 15° C=59° F.

Mr. ERNEST FOWLES: Do you differentiate one mode from another on an interval basis?

Dr. PERRETT: I do not say that the *diesis* of Archytas comes in only in the one place. *On this instrument* it comes in only in one place. It should be possible to divide a major tone harmoniously into three parts, because two chromatic semitones and the *diesis* of Archytas together make up a major tone to within half a cent—a difference that is quite imperceptible.

Mr. FOWLES: Was that fragment part of a Bacchic ode?

Dr. PERRETT: It comes from a chorus lamenting the sad fate of Orestes. It is in the enharmonic genus of the Dorian mode.

Mr. FOX-STRANGWAYS: I think this is a marvellous lecture and I have enjoyed it enormously, as much as I could understand. My trouble in understanding it is that Dr. Perrett, with the very best intentions, has never told us what the thing which he sounds on his instrument is representing. I do not really know what he is trying to tell us.

My impression of Greek music generally is this. First of

all, nothing whatever is known about the rhythm. Secondly, very little indeed is known about the tune. With those two things, I do not think you can call this lecture a lecture on Greek music. You can call it a lecture on Acoustics.

The second point is that I do not think this is a lecture on Greek acoustics, but simply on Acoustics.

We were not told really what precise meaning 7 : 5 or 10 : 7 had, or what the exact point is that they had in the scales. To understand that we should need to have the scale with notes, really to see where they come in.

Then Dr. Perrett in his enthusiasm, after playing the tune that was put on the screen in front of us, proceeded to harmonise. He harmonised for about what one would call three bars. Then one lost oneself, and then he went on for another twenty bars after the tune ought to have finished. I do not know how we can understand that.

I heard Dr. Perrett lecture on a former occasion (before some philosophical society, I think) and I heard his instrument then. The harmonium is a very great improvement on it, because one can at least hear the consecution of the chords. My hearing is not good enough to tell me what the chords would sound like as against what he is actually playing, because I have first to think which is the key-note, then what chord he is sounding, then what it would sound like in equal temperament, and then to compare that with what it *does* sound like. I am afraid it is too much for me.

So if some day he could make it a little clearer, I feel it would be a very interesting lecture indeed.

But may I say that I really did enjoy listening, hoping I could understand? I cannot say any more, though I have the best will in the world.

Mr. LLOYD POWELL : Did I understand from your lecture that Greeks did harmonise their melodies or that they did not?

Dr. PERRETT : There is no evidence at all of more than two notes sounding together at any time.

Mr. LLOYD POWELL : Then your examples have nothing to do with Greek music. They would never have harmonised it?

Dr. PERRETT : I think they did in their best period before they tempered their scale and lost harmonies altogether. Their tempered thirds were dreadful.

Mr. LLOYD POWELL : Then you mean that in their best period they would have sounded more than two notes simultaneously?

Dr. PERRETT : I think only in arpeggios.

Mr. HUNT : I would like to ask one question. You played us the German sixth just now so that it sounded as a concord, and I believe it is possible to play on that instrument a dominant seventh sounding as a concord. Is it possible to make discords, which have been known as the dominant ninth, eleventh and thirteenth, sound as concords?

Dr. PERRETT : I have not sounded a dominant seventh at all. Ellis went on another very important step, from seven, that is fourteen, to seventeen, and that makes a new triad, or division of a perfect fifth, 14 to 17 to 21. I have heard it because I have tuned one or two reeds temporarily to this ratio, and then I have had to tune them back. If this A^b is flattened by seven cents it becomes the 17th harmonic of G. The 17th harmonic here would spoil the note I have already got and want. A great many desirable notes are missing on this instrument.

Mr. HILEY : Perhaps Dr. Perrett will tell us what he did when he multiplied the three or four bars into about twenty? I did not quite follow that process.

Dr. PERRETT : I just put in what is called *remplissage*. That is all. There are numerous gaps in the fragment. If your melody breaks off, leaving gaps, you must fill them up somehow to make the thing continuous. I did perhaps exceed my time allowance, but I cannot plead guilty to anything else.

CHAIRMAN : I am afraid the lantern has gone away. Otherwise I think we might have asked you to go over that quotation in your own notation again.

Mr. BROADWOOD : There were, were there not, certain modes which were considered definitely bad to use in ancient Greek music? It seems extraordinary that certain modes were considered vulgar and others not. For instance, certain modes only were used for the Bacchanalian music.

Dr. PERRETT : The late Théodore Reinach studied Greek music for forty years, and at the end said he had not an idea what the modes meant. They constantly shifted, and what was supposed to be very fine at one time was supposed to be very bad at another. This enharmonic genus, which Aristoxenus writes about as something wonderful, came to be an object of extraordinary dislike in the time of Aristoxenus himself.

Mr. BROADWOOD : Were certain modes not allowed to be sung except by women?

Dr. PERRETT : I cannot say. The literature is so voluminous, I cannot claim to have read one-twentieth of it. I do not think I ever shall.

Mr. FOX-STRANGWAYS : Could you sound a 5/7 and then an ordinary inversion of it?

Dr. PERRETT did so, and added : I have tuned the instrument very accurately for 62°, and I know that a change of 5° either way makes the thing go sour like cream in thunder weather. I believe that the difference of 2° F. is noticeable. It is not a matter of fine musical ear at all. It is quite mechanical.

You will find the figures in the late Lord Rayleigh's *Theory of Sound*, which may be acoustics, but is also an extremely fine book. It has been shown by an immense amount of experiment that no ear can distinguish melodically two notes in succession which do not differ by more than point three of a vibration in the most sensitive part of the scale, but when two notes are sounded together, as Lord Rayleigh shows, there is no limit to the fineness of discrimination by the method of beats. I believe that is the only instance in which any human sense is capable of an unlimited fineness of discrimination; but it does not mean that you must have a very keen musical ear in order to do it. It is simply that you get alternations of sound and silence. Anybody can note them.

Miss SCHLESINGER : If one gets the original notes that correspond with the notation of the *Tonos* in which the fragment is noted, one gets a somewhat different version of the *Orestes*.

Dr. PERRETT : I follow Reinach in taking it to be the Dorian mode. Emmanuel's treatise is the most illuminating of all I have read. I have got more help from Emmanuel than from anybody else—except, of course, Wallis.

Miss SCHLESINGER : I believe that Maurice Emmanuel bases upon Bellermand's interpretation of notation? It will be proved before long that Bellermand's interpretation of Greek notation makes arrant nonsense of the whole thing. The one point which he held to be infallible, *i.e.*, the same tetrachordal unit throughout every *Tonos* has been proved a fallacy, if one follows Bellermand's own evaluation of the symbols of notation given by Alypius.

The CHAIRMAN then adjourned the meeting after thanking Dr. Perrett.