II. "Tonometrical Observations on some existing Non-harmonic Musical Scales." By ALEXANDER J. ELLIS, B.A., F.R.S., assisted by ALFRED J. HIPKINS (of John Broadwood and Sons). Received October 30, 1884.

Musical Scales are said to be Harmonic or Non-harmonic according as they are or are not adapted for playing in harmony.

Most accounts of non-harmonic scales, such as the Greek, Arabic, and Persian, either (1) are derived from native theoreticians, who give the comparative lengths of the strings for the several notes, whence, on the assumption that the numbers of vibrations are inversely proportional to the lengths (which is only approximately correct in practice), the intervals from note to note are inferred; or (2) are attempts to express the effects of the intervals by the European equally tempered scale. The former when reduced, as in Professor J. P. N. Land's "Gamme Arabe," 1884, is the best that can be done without hearing the scales themselves. The latter is utterly delusive and misleading.

Having about 100 tuning-forks, the pitch of each of which has been determined by Scheibler's forks (see "Proc. Roy. Soc.," June, 1880, vol. 30, p. 525), and having had an opportunity of hearing the notes themselves produced on various instruments, and having had the great advantage of being assisted by Mr. A. J. Hipkins's musical ear, which is wonderfully acute to detect and estimate minute differences of pitch, and without which I could have done little,* I have been able, I believe for the first time, to take down the actual pitch of the notes in various existing non-harmonic scales far better than it was possible to do with the siren or the monochord, which are not only difficult to manipulate and to carry about, but at the best are very apt to mislead. Where it was impossible actually to hear the sounds, I carefully measured the comparative vibrating lengths of the strings producing the notes on fretted instruments, whence, with by no means the same certainty, the scales could be inferred. But I have not here noted these measurements or their results, unless I could contrast them with the intervals obtained by measuring the actual pitch of the notes produced on the instruments themselves, as in the cases of India and Japan.

But the mere statement of the numbers of vibrations, or of the vibrating lengths of the strings producing a scale, conveys no musical notion whatever to a musician. He wants to know how many equally

* Throughout this paper, "we" and "us" relate to Mr. Hipkins and myself jointly, and all measurements of numbers of vibrations made by us rest on the judgment of Mr. Hipkins's ear with respect to the position of the note heard between two forks, of which I had previously determined the pitch, or their Octaves.

tempered Semitones, or parts of such Semitones, are contained in the interval, so that he can realise it somewhat, as compared with the notes of a modern piano, which are intended to be tuned in equal temperament.* This transformation is easily effected by the following brief table, premising that for brevity I use *cent* for the hundredth part of an equally tempered Semitone, of which there are twelve to the Octave.

To convert tabular logarithms into cents, and conversely—

Cents.	Logs.	Cents.	Logs.	Cents.	Logs.	Cent.	Logs.
100	·02509	10	·00251	1	·00025	·1	·00003
200	·05017	20	·00502	2	·00050	·2	·00005
300	·07526	30	·00753	3	·00075	·3	·00008
400	·10034	40	·01003	4	·00100	·4	·00010
500	·12543	50	·01254	5	·00125	·5	·00013
600	·15051	60	·01505	6	·00151	·6	·00015
700	·17560	70	·01756	7	·00176	·7	·00018
800	·20069	80	·02007	8	·00201	·8	·00020
900	·22577	90	·02258	9	·00226	·9	·00023
1000	·25086						
1100	·27594						
1200	·30103						

take the logarithm of the interval ratio and seek the next least in the first column of the table; then the next least to the difference, and so on, taking the cents opposite. Generally it suffices to take to the nearest cent, as that expresses an insensible interval. Thus, if the numbers of vibrations are 440 and 528, the difference of their logs. is ·07918; the next least in the first column, ·07526, gives 300 cts., with remainder, ·00392; the next least to which in the second column, ·00251, gives 10 cts., and remainder, ·00141; the next least to which in the third column, ·00125, gives 5 cts., and remainder, ·00016, which in the fourth column gives ·6 ct. Hence the interval is 315·6 cts., for which usually 316 cts. is sufficient to write. Now this shows that the interval contains 3 equal Semitones, and 16 hundredths of a Semi-

* The first person to propose the measuring of musical intervals by equal Semitones was, I believe, de Prony, but I have not been able to see his pamphlet; the next was the late Professor de Morgan ("Cam. Phil. Trans.," x, 129), from whom I learned it, and I employed it in the Appendix of my translation of Helmholtz, by the advice of Mr. Bosanquet. Having found that two places of decimals sufficed for most purposes, I was led to take the second place, or hundredth of an equal Semitone as the unit, and I have extensively employed this practice, here for the first time published, with the greatest advantage. In fact, I do not know how I could have expressed the results of the present investigation in any other brief and precise, and at the same time suggestive, method.

tone more. It is therefore the just minor Third, and it is written between the notes that form it, thus: *A* 316 *C*.

It is convenient for comparison with what follows, to have the following just intervals expressed in cents :—

Intervals.	Cents.	Intervals.	Cents.
The Skhisma	2	Just major Third, $\frac{5}{4}$	386
The Comma of Didymus, $\frac{81}{80}$	22	Pythagorean major Third, $\frac{81}{64}$	408
The Pythagorean Comma	24	Grave Fourth, $\frac{320}{243}$	476
The Septimal Comma, $\frac{64}{63}$	27	Just Fourth, $\frac{4}{3}$	498
Quartertone	50	Septimal Fifth, $\frac{7}{5}$	583
Small Semitone, $\frac{25}{24}$	70	Tritone, $\frac{45}{32}$	590
Pythagorean Limma, $\frac{256}{243}$	90	Grave Fifth, $\frac{40}{27}$	680
Small Limma, $\frac{135}{128}$	92	Just Fifth, $\frac{3}{2}$	702
Diatonic Semitone, $\frac{16}{15}$	112	Acute Fifth, $\frac{243}{160}$	724
Pythagorean Apotome	114	Just minor Sixth, $\frac{8}{5}$	814
Great Limma, $\frac{27}{25}$	134	Just major Sixth, $\frac{5}{3}$	884
The Trumpet $\frac{3}{4}$ Tone, $\frac{12}{11}$	151	Pythagorean major Sixth, $\frac{27}{16}$	906
The minor Second, $\frac{10}{9}$	182	Natural minor Seventh, $\frac{7}{4}$	969
The major Second, $\frac{9}{8}$	204	Minor Seventh, $\frac{16}{9}$	996
Septimal minor Third, $\frac{7}{6}$	267	Just major Seventh, $\frac{15}{8}$	1088
Pythagorean minor Third, $\frac{32}{27}$	294	Pythag. major Seventh, $\frac{243}{128}$	1110
Just minor Third, $\frac{6}{5}$	316	Octave	1200

In each scale I give the measured number of vibrations with, occasionally, the millimetres in the vibrating lengths of string, the cents in the interval from note to note, and the sum of those cents from the lowest note to the note considered. From the latter, considering the lowest note to be *c* in all cases, it is easy to deduce the name of the nearest equally tempered note, and show how many cents must be added to it or subtracted from it to give the note heard, by remembering that—

c	*c*♯ or *d*♭	*d*	*d*♯ or *e*♭	*e*	*f*	*f*♯ or *g*♭	*g*	*g*♯ or *a*♭
=0	100	200	300	400	500	600	700	800

a	*a*♯ or *b*♭	*b*
900	1000	1100

It must be borne in mind that I give the actual intervals heard from or measured on actual instruments, and that these, we may safely say, *never* represent the intervals intended by the tuner, within from 5 to 20 cents either way, on account of the extreme difficulty of precise tuning, especially when the intervals are non-harmonic. European ears are at present satisfied, on our theoretical equally tempered scale, with Fifths too flat, and Fourths too sharp by 2 cts., with major Sevenths too sharp by 12 cts.; major Thirds too sharp by

14 cents, and major Sixths too sharp by 16 cents, while of course the minor Sixths are 14 cts. too flat, and the minor Thirds 16 cts. too flat. That is to say, these would be the errors if the tuning were perfect. The practice, as I have determined by actual measurement, is necessarily far from being restricted to these limits. Hence the results here given have to be compared with many other results from other instruments of the same kind, tuned by different tuners before the intended intervals could be, if they ever can be, satisfactorily determined. In the meantime we know that native ears have actually been satisfied by the intervals here given.

It must also be remembered that as the tones heard were often exceedingly brief (as from wood harmonicons), or very impure, being mixed with inharmonic proper tones (as from metal harmonicons, kettles, gongs, &c.), it was generally impossible to count beats, and often even exceedingly difficult to tell within what pair of forks the note heard really lay, so that there is a possible error of two vibrations occasionally, but, thanks to the acuteness of Mr. Hipkins's ear, it is not probable that the error at any time exceeds one vibration in a second. The number determined is therefore purposely given only to the nearest integer.

I. Arabia and Syria.

The theoretical account of Arabic scales is admirably given in Professor Land's "Gamme Arabe." It there appears that one Zalzal, more than a thousand years ago, being dissatisfied with the ordinary division of the Fourth, as—

C	204	*D*	90	*E*♭	114	*E*	90	*F*
0		204		294		408		498

(where the figures between give the number of cents from note to note, and the figures below give the number of cents from the lowest note), introduced a division, which, carried out to the Octave, amounted to—

C	204	*D*	151	q*E*	143	*F*	204	*G*	151	q*A*	143	*B*♭	204	*C*,
0		204		355		498		702		853		996		1200

where q*E* and q*A* mean about a quarter of a tone *less* than (or before coming to) *E* and *A*, and in the same way *E*q, *A*q would mean a quarter of a tone *beyond* *E* and *A*. (In musical notes q will become ꟼ, a turned ♭.)

In later periods this was tempered to a division of the Octave into 24 equal Quartertones, as we learn from Eli Smith, an American missionary at Damascus, who translated Meshāqah's treatise in the "Journal of the American Oriental Society," 1849, vol. i, pp. 171–217. The scale therefore becomes—

C	200	*D*	150	q*E*	150	*F*	200	*G*	150	q*A*	150	*B*♭	200	*C*,
0		200		350		500		700		850		1000		1200

although in the Middle Ages a different scale prevailed in Arabia, to which I need not further allude. Now between Zalzal's time and this mediæval alteration the Crusaders brought the Syrian bagpipe to England, and after it had passed out of fashion in England, it became the national instrument of the Highlands of Scotland.

Such an instrument, made by Macdonald, of Edinburgh, and obligingly played to us by its possessor, Mr. Charles Keene, the well-known artist, yielded on examination the following results :—

Highland Bagpipe.

Vib.*	395	441	494	537	587	662	722	790	882
From vib. ..	g' 191	a' 197	b' 144	c'' 154	d'' 208	e'' 150	f'' 156	g'' 191	a''
Sums from a'.	−191	0	197	341	495	703	853	1009	1200
Tempered ..	−200	0	200	350	500	700	850	1000	1200
Notes		*c*	*d*	q*e*	*f*	*g*	q*a*	*b*♭	c'

The tempered form, therefore, coincides with the Damascus form of Zalzal's scale, which I did not discover till long afterwards. The theory of this scale is lost, but it is usual to make g' to a' rather less than a whole tone, while the two drones, an Octave and two Octaves below a', necessitate a pure Fifth, a' 702 e''. Zalzal divided a Pythagorean minor Third of 294 cents into 151 and 143 cents; the modern instrument divides the just minor Third 316 cents, probably, into 151 and 165 parts. We thus get a possible rationalised form of the bagpipe scale, the first attempted, so far as I know. As usual in bagpipe music, I begin the scale on a'. I have calculated the vibration to the same base a' 441 vib., for both tempered and rational vibrations, to show how close they are to the observed :—

Rationalisation of the Bagpipe Scale.

Observed vib. .	441	494	537	587	662	722	790	882
Tempered vib..	441	495	540	587	661	721	786	882
Rational vib...	441	496	541	595	662	722	794	882
Notes	a' 204	b' 151	c'' 165	d'' 182	e'' 151	f'' 165	g'' 182	a''
Sums of cents .	0	204	355	520	702	853	1018	1200
Ratios	a' 8 : 9	b' 11 : 12	c'' 10 : 11	d'' 9 : 10	e'' 11 : 12	f'' 10 : 11	g'' 9 : 10	a''
Ratio from a'..	1	8 : 9	22 : 27	20 : 27	2 : 3	11 : 18	5 : 9	2

* In these tables the line "vib." contains the number of vibrations determined by us. The line "from vib." contains the notes, in this case those usually given in bagpipe music, but generally merely distinguished by Roman numerals, I, II, III, &c., with the interval between them in *cents*. The line "sums" gives the sums of these cents, interval by interval, that is, the interval between each note and the lowest. The line "tempered" shows the nearest intervals on an equally tempered scale of 24 Quartertones in the Octave. The "notes" sometimes added, as those due to taking 0 as *c*, as already explained.

II. INDIA.

There are two distinct kinds of scales in India, those of harmonicons, most probably from hill tribes, and those of the stringed instruments belonging to the conquering race.

Balafong from Patna in the South Kensington Museum, a wooden harmonicon strung over a beautifully carved case, consisting of 25 bars (of which we measured 14) containing 3 Octaves and 3 notes. The Roman numerals II, III, &c., indicate the successive bars, I was not measured.

Vib.	158		176		194		214		233		259		279		320
From vib..........	II	187	III	169	IV	170	V	147	VI	183	VII	129	VIII	237	IX
Sums	0		187		356		526		673		856		985		1222
Vib.	320		355		391		434		484		531		582		
From vib..........	IX	180	X	167	XI	181	XII	189	XIII	160	XIV	159	XV		
Sums, less 1222..	0		180		347		528		717		877		1036		

Observe IV 356 cents, and VII 856 cents, which compare with Zalzal in I. ARABIA. All the Octaves were too sharp. The old Indian stringed instrument is the *Vina* with frets $\frac{7}{8}$ to $\frac{9}{8}$ inch high, so that by pressing the string behind the fret the pitch can be greatly altered. These frets are shiftable, but are usually fastened with wax. I measured the vibrating lengths of string of many, but I consider the resulting scales not sufficiently trustworthy for record here. This pressing behind the fret is constantly employed to sharpen the pitch by a quarter or half a Tone. The modern *Sitár*, which has practically superseded the *Vina*, is a very long-necked guitar with movable frets. These frets are set for the *rāg* or *rāgini* (tune, key, or mode) in which the musician is going to play. They are high enough above the finger-board to allow pressure behind to exert a sensible effect, but the ordinary method of raising the pitch is to deflect the string by moving the finger with the string transversely along the fret. As, however, the frets are properly set, this deflection is used only for grace notes at the end, suddenly raising the pitch about a quarter of a Tone and returning it to its former position.

H.H. Rája Rám Pál Singh was kind enough to bring his sitár (which he left with me), and setting it in five different manners to play Indian airs to us. After he had done so I measured the position of the frets, so that I could return them to their places. Afterwards we sounded each note, took its pitch, and determined the scale by my forks. This, I believe, is the first time that this has been done for any Indian instrument. The pitch for the open string was not the same as that used by the Rája, for these measurements were not taken till long afterwards, but the relative pitch remained the same. This string, which was an English pianoforte steel wire, replacing the Indian steel wire which was broken, was too thick, and this interfered somewhat with the setting. As I had calculated the intervals in cents from the vibrating lengths, I add these also in millimetres to show how unsatisfactory are the results thus obtained. The I, II, &c., number the frets used which, however, begun at about the interval of a Fifth from the open string.

First setting of the Sitár—

Vib. lengths ...	616		554		503		452		417		380		339		316 mm.
From lengths ...	I	184	II	167	III	185	IV	140	V	161	VI	198	VII	122	VIII
Sums	0		184		351		536		676		837		1035		1155
Vib.	393		437		479		535		584		650		731		800
From vib.	I	183	II	159	III	191	IV	152	V	186	VI	203	VII	156	VIII
Sums	0		183		342		533		685		871		1074		1230

Second setting of the Sitár—

Vib. lengths ...	616		554		530		452		417		380		355		316 mm.
From lengths ...	I	184	II	77	III	276	IV	140	V	161	VI	118	VII	201	VIII
Sums	0		184		261		537		677		838		956		1157
Vib.	393		437		460		535		584		650		693		800
From vib.	I	183	II	89	III	262	IV	152	V	186	VI	111	VII	249	VIII
Sums	0		183		272		534		686		872		983		1232

Third setting of the Sitár—

Vib lengths ...	616		577		518		452		417		389		352		318 mm.
From lengths ...	I	113	II	187	III	236	IV	140	V	120	VI	173	VII	177	VIII
Sums	0		113		300		536		676		796		969		1146
Vib.	393		419		471		535		584		634		707		785
From vib.	I	111	II	203	III	220	IV	152	V	142	VI	189	VII	181	VIII
Sums	0		111		314		534		686		828		1017		1198

Fourth setting of the Sitár—

Vib. lengths ...	612		552		500		466		415		368		337		318 mm.
From lengths ...	I	179	II	171	III	122	IV	201	V	208	VI	152	VII	100	VIII
Sums	0		179		350		472		673		881		1033		1133
Vib.	397		439		486		523		594		671		737		786
From vib.	I	174	II	176	III	127	IV	220	V	211	VI	162	VII	111	VIII
Sums	0		174		350		477		697		908		1070		1181

Fifth setting of the Sitár—

Vib. lengths ...	607		574		492		461		408		384		332		312 mm
From lengths ...	I	97	II	267	III	113	IV	212	V	105	VI	252	VII	108	VIII
Sums	0		97		364		477		689		794		1046		1154
Vib.	395		416		488		525		594		620		737		784
From vib.	I	90	II	276	III	127	IV	214	V	74	VI	299	VII	107	VIII
Sums	0		90		366		493		707		781		1080		1187

I would draw attention to the great difference in all cases between the two last intervals, I to VII, and I to VIII, as calculated from the lengths of the strings and the number of vibrations. This arose from the string lying naturally further above the frets for the last notes, and hence the tension being more increased by pressing the string to the fret. Also observe how nearly III approaches to 350 cents in the first, fourth, and fifth settings, and VI to 850 cents in the first, second, and third settings, taking all from the intervals heard. The Indian system of scales is very complex, and differs much from the European.

III. Singapore.

Mr. Hipkins received a *Balafong* or wood harmonicon direct from Singapore, consisting of 24 bars forming 3 Octaves and 3 notes. We measured the central Octave, beginning at bar 8, as follows :—

Observed vib....	312		344		382		427		470		523		569		626
From vib.	I	169	II	181	III	193	IV	166	V	185	VI	146	VII	165	VIII
Sums	0		169		350		543		709		894		1040		1205
Tempered vib. .	312		340		382		429		467		525		572		624
From vib.	I	150	II	200	III	200	IV	150	V	200	VI	150	VII	150	VIII
Sums	0		150		350		550		700		900		1050		1200

The tempered form is given to show that this is one of the Quarter-tone systems, and the tempered vibrations were calculated to show how near they are to the observed.

IV. Burmah.

The *Patala* or wood harmonicon of 25 small neat bars in the South Kensington Museum, No. 1630—'72, "Engel," p. 16, who gives the scale wrongly. We began at the seventh bar from the end, and took an Octave thus :—

Vib.	300		332		367		408		451		504		551		616
Bars	I	176	II	174	III	183	IV	174	V	192	VI	154	VII	193	VIII
Sums	0		176		350		533		707		899		1053		1246

The Octave is very sharp, and bars 15, 16, 20 were sharp Octaves of II, III, VII, bar 16 being very sharp indeed. Otherwise the Octaves were fair.

A *Balafong*, in South Kensington Museum, with a box decorated with Burmese ornaments, 22 bars, containing 3 Octaves and 1 note. Twelve bars measured from 4th to the 15th. The first 5 formed the end of an Octave.

Vib.	...		...		...		237		258		282		318		353
From vib.	...		...		...		IV	147	V	154	VI	208	VII	181	VIII
Sums	...		...		...		506		653		807		1015		1196
Vib.	353		377		432		485		525		573		641		705
From vib.	VIII	114	IX	236	X	200	XI	137	XII	151	XIII	194	XIV	164	XV
Sums	0		114		350		550		687		838		1032		1196

The sums in the first line have been found by subtraction from that under VIII, which was assumed to be the same as that under XV. The different construction of the corresponding parts of the Octave is thus shown.

The *Keay Wine* in South Kensington Museum consists of 15 kettles or gongs resembling the Javese bonangs, arranged in a circle. III* was cracked, and its pitch is doubtful, as was also that of V*. II and III*, as the latter stood, were practically identical.

First oct. vib...	303		333		334		377		416		449		506		602
From vib.........	I	163	II	5	III*	210	IV	170	V*	132	VI	267	VII	301	VIII
Sums	0		163		168		378		548		680		947		1248
Second oct. vib.	602		622		648		719		796		867		990		1032
From vib.	VIII	57	IX	71	X	180	XI	176	XII	148	XIII	230	XIV	72	XV
Sums	0		57		128		308		484		632		862		934

The kettles were probably all out of tune.

V. Siam.

The *Ranat* in South Kensington Museum is a wood harmonicon with 19 bars, scale wrongly described in "Engel," p. 316. Bar XIII* was of a different kind of wood, and had evidently been inserted as a substitute for the Octave of VI, but was too sharp.

First oct. vib....	323		348		379		433		491		504		585		666
From vib.	VI	129	VII	148	VIII	231	IX	218	X	45	XI	258	XII	225	XIII*
Sums	0		129		277		508		726		771		1029		1254

Second oct. vib.	666		748		794
From vib.	XIII*	201	XIV	103	XV
Sums	0		201		304

The scale is enigmatical.

VI. West Coast of Africa.

This is inserted out of geographical position, because it is a solitary example from Africa, and resembles those immediately preceding in character. A *Balafong* in South Kensington Museum, No. 1080, 1080*a*—'68, "Engel," p. 154, who describes the scale wrongly. We measured nine bars—

Observed vib..	327		357		386		445		497		547		596		654		714
From vib......	VIII	152	IX	135	X	246	XI	191	XII	166	XIII	149	XIV	161	XV	152	XVI
Sums............	0		152		287		533		724		890		1039		1200		1352
Tempered vib.	327		357		389		449		504		550		600		654		
From vib........	VIII	150	IX	150	X	250	XI	200	XII	150	XIII	150	XIV	150	XV		
Sums............	0		150		300		550		750		900		1050		1200		

where the tempering shows that the scale belongs to the system of Quartertones.

VII. Java.

The scales were observed from the instruments of the Javese Gamelang or band, at the Aquarium, in November, 1882, and formed the commencement of these investigations. We were materially assisted by work done on the same instruments (but without determining pitch) by Mr. W. Stephen Mitchell, M.A., of Gonville and Caius College, Cambridge, and by determinations with the monochord of similar instruments in Holland by Professor J. P. N. Land (who also gave me much information), assisted by Dr. Onnes, both of Leyden. Professor Land also kindly communicated the results of the measurements by Dr. Loman and Dr. Figée, both of Leyden. These measurements of distinct instruments are annexed in a reduced form.

There are two entirely different Javese orchestras which cannot play together. We examined three sets of instruments from each—the *Gambang*, or wooden harmonicon, the *Sáron* and *Slèntem*, or metal bar harmonicons, and the *Bonang*, or set of kettles—while in Leyden a *Gĕndér* (another metal harmonicon) and a different *Sáron* were examined.

The first orchestra played *Salêndro*, the second *Pèlog* scales, both Pentatonic; but, as will be seen, completely different. The first had only five notes in the Octave, the second had seven, but used only five at a time, just as Europeans have twelve, but use only seven at a time. The first has no interval between consecutive notes so small as a major Second, or so large as a minor Third. The second has between two consecutive notes of its seven, approximatively two Semitones, (no Tone), three Three-quartertones, and two minor Thirds. The first is very uniform, the second very diverse in its intervals.

First or Salêndro Scales.

Obs. vib. * Out of tune. † Not recorded.

Gambang	*268		308		357		411		470		*535
Sáron (E. & H.) ..	272		308		357		411		471		543
Slèntem	270		308		357		411		469		540
Mean	270		308		357		411		470		540
From Mean	I	228	II	256	III	244	IV	232	V	240	I′
Sums	0		228		484		728		960		1200
Gĕndér, lower oct..	I	191	II	251	III	249	IV	261	V	220	I′
Gĕndér, upper oct. .	I	219	II	256	III	261	IV	223	V	288	I′
Sáron (Land)	I	270	II	200	III	266	IV	239	V	243	I′
Sáron (Figée)	I	275	II	210	III†		IV†		V	243	I′
Tempered vib......	270		310		356		409		470		540
From vib.	I	240	II	240	III	240	IV	240	V	240	I′
Sums	0		240		480		720		960		1200

This tempered form seems to have been that aimed at. It is easily tuned when the ear has become accustomed to the flat Fourth of 480 cents. Tune up I 480 III, and III 480 V. Then from the Octave I′ tune down I′—480 IV, and IV—480 II. Observe that the Fourth is flat and the Fifth sharp, and that V is nearly the natural harmonic Seventh of 969 cents. These are also points of distinction from the next set.

Second or Pèlog Scales.

Obs. Vibrations. * Out of tune.

Gambang	*283		*311		365		391		416		448		*532		*566
Bonang	278		302		361		390		417		448		526		556
Sáron	279		302		360		387		414		447		524		558
Adopted	279		302		361		389		415		448		526		558
From adopted........	I	137	II	309	III	129	IV	112	V	133	VI	278	VII	102	I′
Sums	0		137		446		575		687		820		1098		1200
							Scales.								
Pèlog..................	I	446	...		III	129	IV	112	V	411	...		VII	102	I′
Dantsoe	I	137	II	550	...		...	...	V	133	VI	278	VII	102	I′
Bem (E. & H.)	I	137	II	438	...		IV	112	V	411	...		VII	102	I
,, (Loman)	I	147	II	416	...		IV	96	V	429	...		VII	112	I′
Barang (E. & H.)...	I	137	II	438	...		IV	112	V	133	VI	380	...		I′
,, (Loman)...	I	151	II	426	...		IV	111	V	179	VI	333	...		I′
Miring.................	I	446	...		III	129	IV	245	...		VI	278	VII	102	I′
Menjoera..............	I	137	II	309	III	129	IV	523	...		...	...	VII	102	I′
Tempered vib........	279		304		362		395		418		443		527		558
From vib.	I	150	II	300	III	150	IV	100	V	100	VI	300	VII	100	I′
Sums....................	0		150		450		600		700		800		1100		1200

After giving the three sets of vibrations observed I give that adopted, which is the mean of the second and third set, as the Gambang was evidently rather out of tune, and then the scale of all the seven notes answering to the chromatic scale of our pianos. Then follow the names of the scales really used, formed by selecting five notes from these. Pèlog and Dantsoe (pronounce Dutch *oe* as our *oe* in *shoe*) are given only from our own observations. In Bem and Barang, Dr. Loman's observations made with the monochord in 1879 on another set of instruments are added in a reduced form. These four scales are certain. Miring and Menjoera (pronounce Dutch *joe* like the English word *you*) are conjectural restorations from imperfect indications communicated to me by Professor Land. Finally, I have added a rather hazardous tempering, and shown by calculating the vibrations from it, that it does not materially misrepresent the observed. In these scales the Fourth, IV 575 cents, is nearly the tempered Tritone 600 cents, and the Fifth, V 687 cents, is flatter even than the tempered Fifth 700 cents. This is exactly contrary to the Salêndro scale. Yet I observed one of the players selecting the right bar for his scale by holding it up and tapping it with his finger, showing that the pitch was quite familiar to him.

VIII. China.

Without entering upon any discussion on the very vexed question of Chinese music, I confine myself to giving the scales which (by the kind permission of Mr. J. D. Campbell, one of the Commissioners of Chinese customs representing China at the International Health Exhibition this year, and with the assistance of the secretary, Mr. Neumann), we were able to have played to us by the Chinese musicians attached to that court, in July and August, 1884, at four specially arranged meetings, on their own instruments, together with observations on a duplicate of one of them at the South Kensington Museum, and a set of bells belonging to Mr. Hermann Smith.

1. *Transverse Flute* or *Ti-tsu*, with seven finger holes and an embouchure, open at both ends. Probably in actual playing some of the notes may have been varied by half or quarter covering of the finger-holes. The Heptatonic scale played is given first, and then the notes selected for the more usual Pentatonic scale.

Vib.	240		266		292		311		352		401		454		479
From vib.	I	178	II	161	III	109	IV	214	V	226	VI	215	VII	93	I′
Sums..............	0		178		339		448		662		888		1103		1196
Pentatonic	I	178	II	270	...		IV	214	V	226	VI	308	...		I′

2. *Oboe* or *So-na*, played with a short reed, having seven finger-holes in front and two thumb-holes behind, a loose brass cone of considerable size covered the lower end. Said to be a modern instrument. Sound and intervals resembling the bagpipes.

Vib..................	400		435		475		516		578		640		719		808
From vib.	I	145	II	152	III	143	IV	197	V	176	VI	201	VII	202	I′
Sums	0		145		297		440		637		813		1014		1216
Tempered vib...	400		436		476		519		582		635		713		800
From vib.	I	150	II	150	III	150	IV	200	V	150	VI	200	VII	200	I′
Sums	0		150		300		450		650		800		1000		1200

On this instrument as thus played there was nothing approaching a Fourth of 498 cents, or a Fifth of 702 cents. It must have been modified in playing to work with the flute. Both were orchestral instruments.

3. *Reed Mouth Organs* or *Shêng* (rhymes to *sung*, and often so called), a gourd with its top cut off, and covered with a flat board, in which were inserted 13 pipes, 11 of which had free reeds, which sounded on blowing (or sucking) through the mouth-hole, and stopping a hole in the pipe which the player intended to sound. The lengths of the pipes are ornamental, an internal slot determining the real lengths. The two "dummies" were for holding.

First oct. vib....	450		508		547		600		680		760		820		899
From vib.	I	210	II	128	III	160	IV	217	V	193	VI	132	VII	159	I′
Sums	0		210		338		498		715		908		1040		1199
Second oct. vib.	899		1017		1110		1232								
From vib.........	I′	214	II′	151	III′	182	IV′								
Sums...............	0		214		365		547								
Tempered vib...	450		505		551		601		674		757		825		900
From vib.	I	200	II	150	III	150	IV	200	V	200	VI	150	VII	150	I′
Sums	0		200		350		500		700		900		1050		1200

Here we have a perfect Fourth, IV 498 cents, and a good but sharp Fifth, V 715 cents. But the instrument, if in tune (small free reeds easily fall out of tune), belonged to the Quartertone system.

4. *First Chime of Small Gongs* or *Yan-lo*, a set of 10 small gongs about the size and shape of cheese-plates, arranged with I at the top, II, III, IV in the first row, from left to right behind, where they were struck with a wooden hammer, and then V, VI, VII in the second, and VIII, IX, X in the third row, all hung in a square wooden frame. The Chinese musician played in the order of pitch, omitting IX and I.

Vib.	449		495		555		568		630		663		703		712		830		902
From vib.......	VIII	169	V	198	II	40	IX	179	IV	88	VI	101	X	22	I	265	VII	144	III
Sums	0		169		367		407		586		674		775		797		1062		1208
Played	0		169		367		...		586		674		795		...		1062		1208

Here again there is no approach to a Fourth of 498 cents, or a Fifth of 702 cents.

5. *Second Chime of Small Gongs* or *Yan-lo*, in the S. K. Mus., "Engel," p. 193, who describes the scale wrongly. Although the instrument is of the same appearance as the last, the scale was entirely different, and the compass did not reach 750 cents. We seemed to make out three possible scales which are annexed, but we have no means of knowing if they were designed. One extends to a sharp and another to a flat Fifth, whilst the third reaches an exact Fourth. The gongs are numbered as in No. 4.

Vib.	794		818		912		926		1011		1022		1114		1116		1198		1216
From vib.......	I	52	II	188	III	26	IV	152	VI	19	VIII	149	V	3	IX	123	X	26	VII
Sums	0		52		240		266		418		437		586		589		712		738
Possible scales																			
To sharp Fifth	I	240	...		III	178	...		VI	171	...		...		IX	123	X		
Sums	0				240				418						589		712		
To flat Fifth ...	...		II	188	III	178	...		VI	168	...		V	152	...		...		VII
Sums			0		188				366				534						686
To Fourth......	...		...		III	197	...		...		VIII	152	...		IX	149	...		VII
Sums					0						197				349				498
Tempered......					0						200				350				500

The last is therefore like the first tetrachord in the bagpipe scale, dividing the Fourth into a Tone and two Three-quartertones. There are, however, several curious intervals.

VI 19 VIII nearly a comma of 22 cents.
III 26 IV nearly $\frac{1}{8}$ of a major Tone of 204 cents.
I 52 II exactly $\frac{1}{4}$ of a major Tone of 204 cents.
II 188 III and III 178 IV are both nearly the minor Tone of 182 cents.
I 240 III is an exact pentatone, or $\frac{1}{5}$ Octave, as in the tempered Javese Salêndro scale.
II 385 VIII is an excellent major Third of 386 cents.
I 586 V and I 589 IX are both nearly the Zaïd of 588 cents, on the second string of the Arabic lute.

I 738 VII, the complete compass, is exactly the 49th harmonic reduced to the same Octave, which is of course only a curious coincidence.

6. *Dulcimer* or *Yang-chin*, exactly like the ordinary dulcimer (see figure in Grove's "Dictionary of Music," i, 469), with four wires to each note forming two Octaves, the longer wires passing under the bridge which limits the shorter. It is struck with elastic hammers. The instrument being out of tune was tuned for us by the musician who played No. 7, according to the Chinese names of the scale in Dr. William's *Middle Kingdom*, which are there interpreted as the major scale of *E*♭. If the conjectural just scale be correct, this would be the scale of *B*♭ major, beginning on its second note *C*, and is therefore comparable to the Japanese Ritsusen, which is the scale of *C* major begun on its second *D*.*

Chinese names...	Ho		sz'		f		chang		ché		kung		fan		liu.
Vib.	205		226		240		272		300		340		364		409
From vib.	I	169	II	105	III	217	IV	170	V	217	VI	118	VII	202	I'
Sums.	0		169		274		491		661		878		996		1198
Conjectured Just															
Vib.	205		228		243		273		304		342		364		410
From vib.	C	182	D_1	112	$E\flat$	204	F	182	G_1	204	A_1	112	$B\flat$	204	c
Sums	0		182		294		498		680		884		996		1200
Pentatonic form.	C	182	D_1	316		...	F	182	G_1	204	A_1	316		...	c

The tuner had great difficulty in tuning the semitones II 105 III and VI 118 VII, that is, in tuning the notes III and VII. He accomplished the second more easily than the first. The Pentatonic form consists of two disjunct tetrachords, *CF*, *Gc*, each divided into a Tone and a minor Third.

8. *Tamboura* or *Sien-tsu*, a three-stringed guitar with circular body aud long neck without frets. The strings were tuned to 239, 266, and 400 vib., making the intervals 185 and 706 cents, meant for 182 the minor tone, between the first and second, and for 702, a Fifth, between the Second and Third, very fairly tuned indeed. The strings were plucked with bone plectrums, attached to the first joint of thumb and forefinger, and projecting like claws. The tone was good and very like a banjo. Only the following pentatonic scale was played to us:—

Vib.	320		357		400		480		536		642
From vib.	I	189	II	197	III	316	IV	191	V	312	I'
Sums	0		189		386		702		893		1200

* In writing tones in Pythagorean intonation formed by a succession of just Fifths or Fourths from *C*, the ordinary letters are kept unchanged; but for just intonation it is necessary to have a series a comma lower. These have a subscript 1, as D_1, so that, in vibrations, $D_1 : D = 80 : 81$. Similarly another series would be a comma sharper, and be written with a superior 1, as $E^1\flat$, so that, in vibrations, $E\flat : E^1\flat = 80 : 81$.

Conjectural Just											
Vib.	320		356		400		480		535		640
From vib.	C	182	D_1	204	E_1	316	G	182	A_1	316	c
Sums.............	0		182		386		702		884		1200
Transformed sums..	498		680		884		0		182		498

This was again so nearly just that I have conjectured a just restoration, $C\ D_1\ E_1\ G\ A_1\ c$: and if this is transformed, by beginning it with G, or by deducting 702 cents from each of the last sums (previously adding 1200 cents where needed), we obtain the scale G 182 A_1 316 C 182 D_1 204 E_1 316 G, in which the intervals are precisely the same as in No. 7.

9. *Balloon Guitar* or *P'i-p'a.*—The body of the guitar was oval. There were four strings, the lowest tuned to 234 vib., and then its Fourth, its Fifth, and its Octave, but we did not test the accuracy of these intervals, which were tuned by the same musician who tuned Nos. 7 and 8. Near the nut were four large, round-backed, semi-elliptical frets, joining each other at bottom. These the player did not use. But on two examples of the S. K. Museum, I conjectured by measuring the strings, that they were intended to give such a tetrachord as—

C	204	D	90	$E\flat$	114	E	90	F
0		204		294		408		498

or their just or tempered forms. There were 12 frets on the body of the instrument. They were high but broad at the top. We did not test each, but merely took down the following pentatonic scale :—

Observed vib..	320		348		392		465		530		638
From vib.	I	145	II	206	III	296	IV	227	V	321	VI
Sums	0		145		351		647		874		1195
Tempered vib..	320		349		392		466		538		640
From vib.	I	150	II	200	III	300	IV	250	V	300	VI
Sums	0		150		350		650		900		1200

The tempered scale agrees well in all notes but V. The scale is so remarkable in every way, though it did not sound amiss, that I suspect the frets to have been inaccurately placed ; they were bits of wood roughly glued on.

This completes our observations with the Chinese musicians. I measured also the vibrating lengths of strings in two other P'i-p'as, and also two Moon Guitars or *Yueh-chins* in the S. K. Museum. One of the latter seemed intended for equal temperament of 12 Semitones, and it is the only Chinese instrument which has suggested this to me ; the other looked like an attempt to divide the Octave into eight Three-quartertones, and had at any rate eight tones to the Octave forming nearly those intervals. But as I did not try these with forks I do not record them.

10. *Small Chime of Bells*, belonging to Mr. Hermann Smith. Four small bells of which the largest was 45 mm. in diameter and 13 mm. in height, arranged on a stem passing through them and framed in a lyre-shaped wire.

Vib............	761		912		1004		1156
From vib.......	I	313	II	167	III	244	IV
Sums...........	0		313		480		724

The I 313 II is nearly a perfect minor Third of 316 cents. The III and IV give almost precisely the Javese Salêndro observed III 484, and IV 728, so that the interval between them, 244 cents, is almost precisely a Pentatone of 240 cents, or $\frac{1}{5}$ Octave. If indeed II were flatter, the notes of the bells might pass as part of such a scale.

IX. Japan.

In the Educational Section of the International Health Exhibition of 1884 there was a considerable collection of Japanese instruments, but there were no players. The only instruments which we could try therefore were a Shō (the Chinese shêng (see China, 3), but different in the number and pitch and intervals of the notes) and a Biwa, or four-string fretted lute. The Shō we found to be out of tune, as referred to the scale exhibited, and to be impossible to blow satisfactorily. The Biwa I first tried by measuring the lengths of the strings, and afterwards with Mr. Hipkins, by tuning the strings arbitrarily and taking the pitch from each fret. These results I record, because in addition to the examples from India, they show very well that measurements of lengths are only an approximation to the speaking values of the strings, and that the latter vary considerably with the thickness of the strings. This has an important bearing upon the theoretical determination of scales given by the divisions of the string. The results for India were valuable in this respect, but they were not altogether satisfactory, because the string was English and too thick. In the present case we had the genuine Japanese strings.

The *Biwa* is a large and heavy but handsome instrument, well made and finished, and answers exactly to Al Fārābī's lute in Professor Land's "Gamme Arabe," the four strings nearly coinciding at the nut, passing over a semi-circular depression to the large tuning pegs, and spreading out to a convenient distance apart by the bridge, so that the plectrum, made of hard wood, spread out like the head of a halbert, could easily be inserted between the strings, or pass over them in rapid succession for arpeggio chords for which the instrument seems to be much used in accompaniments, judging from some music written for it in Japan, on the European staff, the original of which I saw. The diameters of the strings, which seemed to be of hard-corded silk, taken by one of Elliott's micrometer gauges, were 1·65, 1·37, 1·06, and 0·88 mm. in diameter respectively. The variations of interval, however, with the thickness of the string appear not to follow any precise law. The frets were high and about 5 mm. wide of the top, made of hard wood. I was very careful to press on the top of the fret, so that the tension of the string might not be increased, and the action should take place from the edge of the fret nearest the bridge. But possibly I may not always have pressed near enough to the edge, so that the string was slightly lengthened and the pitch flattened. Of course nothing like such accuracy would be reached by the player.

Lengths..............	843		750		709		673		637 mm.
From lengths.........	I	202	II	97	III	90	IV	95	V
Sums................	0		202		299		389		484
Lowest string.									
Vib..................	166		189		201		211		223
From vib.............	I	225	II	107	III	84	IV	96	V
Sums................	0		225		332		416		512
Second lowest string.									
Vib..................	167		190		203		214		223
From vib.............	I	223	II	115	III	91	IV	71	V
Sums................	0		223		338		429		500
Second highest string.									
Vib..................	226		253		272		286		301
From vib.............	I	195	II	125	III	87	IV	89	V
Sums................	0		195		320		407		496
Highest string.									
Vib..................	300		339		361		381		401
From vib.............	I	212	II	109	III	93	IV	89	V
Sums................	0		212		321		414		503
Mean from vib.........	I	214	II	114	III	89	IV	86	V
Sums of mean	0		214		328		417		503
Possibly..............	I	204	II	114	III	90	IV	90	V
Sums................	0		204		318		408		498

Hence the division was probably meant for Pythagorean, the last sums giving *C D D♯ E F*, which should have been *C D E♭ E F*, that is, the second Semitone should have been of 114 cents, and the first of 90 cents. Now it appears from the Report of Mr. Isawa, Director of the Institute of Music, Tokio, Japan (founded October, 1878), an English translation of which, prepared at the Institute, was in the Section, that Japanese theory considers its Semitones to be 12 equal divisions of the Octave, just as in Europe we so consider our 12 Semitones.* Hence these divisions are taken, and are used as—

C	200	*D*	100	*E*♭	100	*E*	100	*F*,
0		200		300		400		500

as they would be played on the pianoforte.

This Report contains an account of the Japanese scale, from which, to complete this notice of Japan, although not tonometrically observed, I may cite the following, where all notes may be provisionally considered as those on the piano.

Classical Scales.

Riosen	*D*	*E*	*F*♯	*G*♯	*A*	*B*	*C*♯	*d*
In descending often	*D*	*E*	*F*♯	*G*	*A*	*B*	*C*♯	*d*
Pentatonic	*D*	*E*	*F*♯		*A*	*B*		*d*
Ritsusen	*D*	*E*	*F*	*G*	*A*	*B*	*C*	*d*
Pentatonic	*D*	*E*		*G*	*A*	*B*		*d*

Popular Scales—Heptatonic.

First Heptatonic	*D*	*E*♭	*F*	*G*	*A*	*B*♭	*C*	*d*
Second „	*D*	*E*♭	*F*	*G*	*A*♭	*B*♭	*C*	*d*

Popular Scales—Pentatonic.

Hiradioshi	*G*	*A*	*B*♭	*D*	*E*♭	*G*
Akebono I.	*G*	*A*	*B*♭	*D*	*E*	*G*
Akebono II.	*A*	*B*♭	*D*	*E*	*F*	*A*
Kumoi I.	*G*	*A*♭	*C*	*D*	*E*♭	*G*
Han-Kumoi	*G*	*A*	*C*	*D*	*E*♭	*G*
Iwato	*G*	*A*♭	*C*	*D*♭	*F*	*G*
Han-Iwato	*G*	*A*♭	*C*	*D*	*F*	*G*

where observe the numerous examples of the most ancient Greek tetrachord of Olympos, consisting of a Semitone followed by a major Third.

* Professor Ayrton, F.R.S., who was present when this paper was read, and who had returned from Japan only a few years ago, made some remarks to which with his permission I will here refer. He said that it was a mistake to suppose the Japanese musical intervals to be like the European. He had examined Japanese instruments when tuned in their different ways by natives, and taken the pitches of the notes by means of a siren, and he had found the intervals very different. My paper in this part merely professes to give Mr. Isawa's theory, without citing his confirmatory experiments, which I did not consider conclusive.—A. J. E.