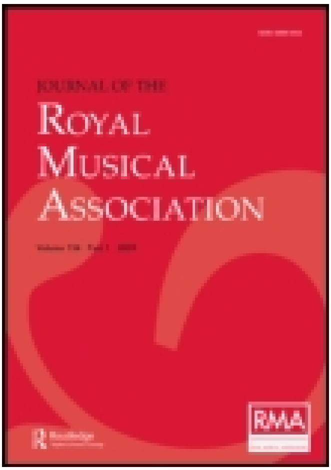

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Notes on the Trumpet Scale

D. J. Blaikley
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H. C. BANISTER, Esq.,

In the Chair.

NOTES ON THE TRUMPET SCALE.

By D. J. Blaikley.

At a recent meeting I accepted a suggestion made by a member of our Council, and agreed to put together a few notes on the trumpet scale, at the time believing that these notes would merely fill up the few minutes that might remain over from the reading of a more important paper. I now find that my few remarks are to provide the whole subject-matter for this evening's meeting, and can only trust that you will accept them rather as suggestions for discussion and exchange of views, than as forming a paper such as those to which you are accustomed.

The expression "the scale of nature," or "the natural scale," is sometimes used as if it implied a precise definition; but among those who so use it, we will find that some have in their minds the natural harmonic scale, while others apply it to our modern major diatonic scale, which, although comprised in the former, does not coincide with it note for note.

If by the words "natural scale" we understand a succession of notes produced by natural phenomena, or from natural objects as distinguished from carefully constructed musical instruments, a little investigation in acoustics soon shows that there are many natural scales, of which one is the harmonic scale and the others are inharmonic. In text-books on acoustics it is customary to direct attention to the natural harmonic scale as obtained by the sub-division of vibrating strings or columns of air in tubes, but as strings or tubes sufficiently accurate in dimensions to give these harmonics correctly are very far from being natural objects, I hold that it is of more importance to keep in view the great natural law that the wave originated by every powerful vibration departs from the simple pendular form, and that the resulting vibration is that due to the natural harmonic partials sounding with their prime. These partials are easily heard by means of resonators.

As an experiment a tube, such as an ordinary lamp chimney, may be partly sunk in a jug of water, and the ear held close by it while a medium or low pitched note is sung or played. As the exposed length of tube is varied, different partials can easily be heard.

A student who has experimented with his own voice and such a resonator for half-an-hour, cannot fail to be impressed with the fact that the source of the harmonic scale is truly natural, and his impressions will probably be so vivid that he will be convinced of the futility of ignoring the existence of this scale in the study of harmony.

Inharmonic natural scales or sequences of notes may be heard in the clanging of masses of metal, or in the tones produced by the striking of plates or bars of regular dimensions, strained membranes, &c. In some cases both the harmonic and an inharmonic scale are given off simultaneously, as when a light tuning-fork is struck.

Experiment: A fork, *c* 128, on being struck and held successively over resonators tuned to its prime, octave, and twelfth, *c*, c^1, g^1, excites the resonators to respond to these partials, and in this case the harmonic components of the tone-mass are due merely to the comparatively great amplitude of the vibration of the fork; they are set up outside the fork; and the one or more inharmonic components arise from the subsidiary vibrations of the fork itself as an elastic bar.

From such instruments as the trumpet, as is well known, we obtain the best practical rendering of the natural harmonic scale, and I have therefore headed this paper, "Notes on the Trumpet Scale." At the same time, I would avoid committing myself to the view that all the notes on the trumpet necessarily follow the harmonic series; as a matter of fact, the lower notes diverge considerably from it. The explanation of the causes for this divergence would, however, take us too far away from the points I particularly wish to bring before you. The use of the term "The Trumpet Scale" is merely to enable us to pass from the abstract to the concrete in the consideration of the harmonic scale.

Perhaps the most striking feature about this scale is the varying effect upon our ear of successive increments of equal numbers of vibrations. In nature's wonderful way, similarity and variety are interwoven. If we start with the lowest F on the piano of about 45 vibrations and trace up the intervals lying between successive additions of 45 vibrations, we find that this difference when added to the prime gives the octave (the most decisive and easily recognised of all intervals) and causes an alteration of only about a quarter-semitone in the upper part of the sixth octave (63 to 64), a difference which to many ears might easily pass unnoticed.

The difference between the values of adjacent intervals, which is very manifest to the ear in the lower part of the scale, octave, fifth, fourth, &c., is less appreciable as we rise, and yet, I submit, should not be ignored when the physical basis of music is under consideration. The central fact is that no two succeeding intervals are alike, and to this reference will again be made.

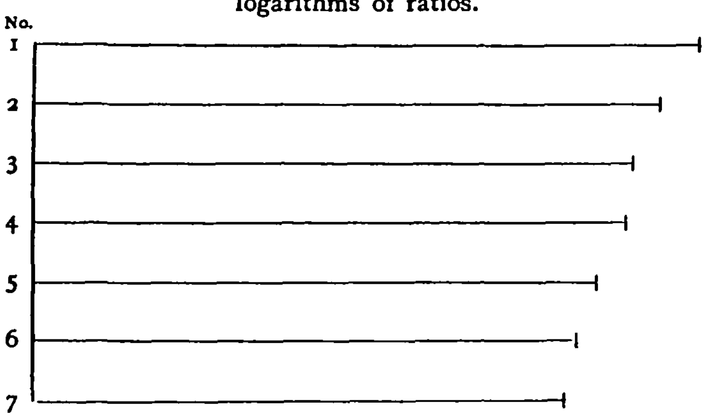
Another important point to bear in mind is that no succession of similar intervals lying within an octave can produce an octave or a multiple of octaves; whether we take perfect fifths, perfect fourths, major or minor thirds, major or minor tones, there is the same difficulty. For instance, a succession of three major thirds $(\frac{5}{4})^3$ is less than an octave, and a succession of four minor thirds $(\frac{6}{5})^4$ is greater than an octave.

As regards the identity between certain of the natural harmonics and the notes of the common chord, there is no difference of opinion; it is only when the derivation of the subordinate notes of the diatonic scale from the harmonic scale is under examination that some rather strained applications of the science of numbers are apt to creep in. In science and art, we usually expect to find theory more rigorous than practice; but in this matter of the diatonic scale we find that arguments have been suggested in theories, which no conductor would tolerate if put into practice in his orchestra.

We may here compare a few numerical values. The octave, fifth, fourth, major third, and minor third, as defined by the ratios, $\frac{2}{1}$, $\frac{3}{2}$, $\frac{4}{3}$, $\frac{5}{4}$, $\frac{6}{5}$, are definitely accepted. The tone is a term more vaguely used, and either the major or the minor tone is equally entitled to the description "natural tone." The term "natural semitone" is still more indefinite, for there is nothing more natural about the interval lying between the fifteenth and sixteenth harmonics (the interval usually called the "natural semitone") than there is about any other natural interval which is approximately a semitone. Indeed, the interval $\frac{16}{15}$ has less claim to be called a semitone than any one of the other six given with it in the following table:—

TABLE OF SEMITONES.

Graphic representation of intervals as expressed by logarithms of ratios.



No.	Ratio.	Logarithm of Ratio.	Interval in Harmonic Series.	Equivalent Value.
1	$\frac{16}{15}$	·02803	b to c	Fourth, less major third.
2	$\frac{17}{16}$	·02633	c to c♯	
3		·02509		Eq. temp. semitone.
4	$\frac{18}{17}$	·02482	c♯ to d	
5	$\frac{19}{18}$	·02348	d to d♯	
6		·02264		Fourth, less two major tones, or Greek hemi-tone.
7	$\frac{20}{19}$	·02228	d♯ to e	

The perfect fourth, ratio $\frac{4}{3}$, is not to be found in the harmonic scale, in the position in which it is placed as the subdominant in the diatonic scale. As Dr. Pole justly puts the matter, "natural harmonics give no suggestion of a fourth above the fundamental." The attempt to connect this note with the eleventh harmonic, the trumpet *f* (so-called), is one of those strained applications of theory to which I have alluded. Let us compare the numbers: they are $10\frac{2}{3}$ against 11, or in whole numbers 32 against 33. If we take the low piano F of 45 vibrations as generator, we have 480 against 495, a difference of 15 vibrations in that part of the scale in which a difference of about 30 vibrations is the most unbearable possible. I am far from saying that the eleventh harmonic may not be a good thing in itself; it exists, and we cannot avoid hearing it, whether we do so with consciousness of its presence or not, but it should no more be confounded with the subdominant than scarlet should be confounded with crimson. *I will here quote a few words from the late Sir George* Macfarren's Preface to Day's Harmony, words which appear to me to be admirable in themselves, and yet strangely at variance with some points in the theory he was then introducing and commending. The words are: "I for one am thankful to equal temperament for the music it renders practicable upon keyed instruments; but although I bow to the necessity of limiting the sounds within an octave to 12, I insist that this expedient conventionality affects not the laws of nature upon which alone sound theory can be based, and that the student ought to know what *should* be, though forced to practise what *must* be."

Although the subdominant does not exist in the harmonic series, and although we cannot (at least in my opinion) properly take the eleventh harmonic as a substitute for it, yet there is no difficulty in finding every note of the diatonic scale in the harmonic series if we give up the idea of the tonic being the generator or root of the scale. The first perfect fourth on the harmonic scale is given by its third and fourth notes. If we carry the series up so as to include the octave between the twenty-fourth and the forty-eighth harmonics we can choose from these harmonics the eight notes of the major diatonic scale in absolutely just intonation and without any "cooking" of figures at all.

To some minds, the idea of having to look for the true tonic or generator in the subdominant will be an objection to this view of the source of the diatonic scale, but to those who remember how modern, comparatively speaking, and how purely arbitrary in its selection of harmonics our diatonic scale is, this objection will not seem very serious. Although Rameau does not appear to have boldly built his theory upon this view, he comes very near it when he says: "The succession of fifths, fa, ut, sol, in which ut holds the middle place, may be regarded as representing the mode of ut."

A more pertinent objection is perhaps to be found in the fact that notes lying so high in the series could never have been habitually produced from any known instrument in such a way as to suggest the scale.

Another view may be considered. The natural harmonic scale, with its intervals lessening gradually, although, as measured by difference of vibrations, absolutely identical, may be compared to an avenue of trees, which, though equally spaced, appear to the eye of the observer to stand closer and closer together as they recede. The pleasure derived by the eye from the arrangement soon lessens: the law determining the intervals is, as it were, too obtrusive, and there is a craving for a little variety in the symmetry. Some such impression as this may be conveyed to the ear by the harmonic scale, leading to a desire for variation, consistent and not inconsistent with law. It has been argued, I think, that certain notes of the harmonic scale, as the seventh and the eleventh, are inadmissible, because they stand in the way of the definition of the scale; but I venture to think that the real reason may be, that they define the scale or law of sequence too strongly and exclude even the bare idea of transition or modulation.

If we, instead of selecting the notes requisite to form the diatonic scale of C from among the higher harmonics of the generator F, choose some from F and some from C, we obtain the complete scale from the lower harmonics, some of the notes being common to both natural scales.

	Harmonic Scale of C.	Diatonic Scale of C, as derived from Harmonic Scales of C and F.	Harmonic Scale of F.	
16	c	c	c	12
15	b	b		
				11
14	$^{7}b^{b}$			
		a	a	10
13				
12	g	g	g	9
11	(trumpet f)			
		f	f	8
10	e	e		
9	d	d	$^{7}e^{b}$	7
8	c	c	c	6
7	$^{7}b^{b}$			
			a	5
6	g			
			f	4
5	e			
4	c		c	3
3	g			
			f	2
2	c			
			f	1
1	c			

Comparing the notes 8, 9, 10, 11, 12, or *c*, *d*, *e*, trumpet *f*, *g*, harmonic scale, with 8, 9, 10, $10\frac{2}{3}$, 12, or *c*, *d*, *e*, *f*, *g*, diatonic scale, we find that by the former we are more tied up to the idea of the generator than by the latter; the subdominant introduced into the diatonic scale suggests to the ear the possibility of escaping from a too rigid adherence to one generator.

Since the time of the Greeks, European music has seen the perfect fourth divided into two tones and a semitone, but it may fairly be a question in the history of musical science whether this highly artificial division is the oldest. The late Carl Engel held the opinion that wind instruments have a historical precedence over string instruments, and when we remember that the production of good strings and soundboards indicates a tolerably high stage of civilisation, this opinion seems a sound one. Probably instruments of the horn and trumpet kind preceded lyres and harps, and on horns, the second and the third fourths, which comprise smaller intervals, are thus divided:—

$$\overbrace{\underbrace{6, 7, 8}_{\text{fourth}} — \underbrace{9, 10, 11, 12}_{\text{fourth.}}}$$

It is not unreasonable to suppose that such divisions of the fourth would be accepted and copied on other instruments. As an opportunity of putting this idea to the test, I examined with much interest the Egyptian flutes discovered by Mr. Flinders Petrie, and found that on one of them the interval of the fourth was divided exactly as it is on the harmonic scale, from the ninth to the twelfth notes.*

Again, we find this sub-division of the fourth surviving on the Highland bagpipe chanter, according to the best measurements I have been able to make, and it is to the lowest note of the tetrachord that the drones are tuned in octaves. The drones are in A, and on the chanter the G may have been added below, much in the same way as the Greeks added a tone below their lowest tetrachord.

In concluding these notes I would remind members of the Association that much interesting matter bearing upon the subject has been brought before them in papers by the late Mr. C. E. Stephens, by Mr. Prout, Mr. Gerard Cobb, Mr. Breakspeare, and by other members.

DISCUSSION.

The CHAIRMAN.—I am exceedingly sorry that a paper prepared with such care and learning as that to which we have listened has not been heard by more of our members. I will ask those present to give our best thanks to Mr. Blaikley for his admirable address.

(A vote of thanks was unanimously passed.)

The CHAIRMAN.—Did I understand rightly about that question of the difference of the octaves, that you attribute it to the temperament of the tuning of the piano, or do you mean to the natural octaves?

Mr. BLAIKLEY.—I was merely speaking of the effect of increments of equal numbers of vibrations, a given number

* Musical Association reports, Session 1890-91, p. 32.

in the lower part of the scale causing so very different an impression upon the ear to the same number in the upper part. There is no question of temperament.

Mr. Gilbrt Webb.—I do not think I quite understand Mr. Blaikley about harmonic and inharmonic tones being generated from a sonorous body at the same time.

Mr. Blaikley.—I purposely omitted that point because it would take a long time to explain. It is really a matter of mechanics rather than of music. If a vibrating body, such as a tuning fork, makes a very small excursion in comparison with the length of the wave, the resulting wave is one of simple pendular form—that is to say, there are no harmonics in it. If, on the other hand, the fork or any other body makes a large excursion in originating the sound wave, the form of that wave would be one that can be resolved into several component parts. It is a question of intensity.

Mr. Webb.—It is interesting to find that our modern diatonic scale approaches so closely some forms of the scales of the ancient Egyptians, and it seems reasonable to infer that our major scale is based on the harmonic scale of nature, as producible from a pipe, &c. If so, it is a strong argument in favour of the theory that the use of pipes preceded the employment of stretched strings as musical instruments. At the same time it appears to me that we sometimes attribute too much importance to the scales. They exist in different parts of the world in great variety, and in many cases are obviously the outcome of certain melodic intervals, which have been adopted by men under various conditions, as the best musical expression of their emotions. In other words, although all scales may have a common origin in nature's scale, their subsequent different forms have resulted from general adoption of certain melodic phrases or idioms. Certain emotions crave for musical expression by greater intervals than others, and it is probable that the smaller intervals, at least of every scale, have been dictated by a desire to obtain certain emotional expression, rather than by the wish to complete a scale, or by conscious imitation of the smaller intervals of the harmonic column. Scales, in fact, vary in form with different generations of men, and would seem to be dependent on climate and the mode of thought of certain periods. Hence it is probable that one or two notes only in any scale are really attributable to the harmonic scale of nature.

Mr. Naylor.—One of the most interesting things that I heard was the scale played upon that pipe. Did I understand the scale of the chanter to be the same as that of the Egyptian flute as far as it goes?

Mr. Blaikley.—As far as it goes.

Mr. WEBB.—Is there any great variety of intervals in the bagpipe scale?

Mr. BLAIKLEY.—Different chanters vary a little. I should add that my remarks are based upon mean results from the instruments I have myself tried and compared with results quoted by the late Mr. A. J. Ellis. It is confusing in hearing them played, and difficult to determine the intervals without measurement, because one is not accustomed to them, but the pipers, who are, seem perfectly satisfied with them, and can easily discern slight departures from their standard.

Miss PRESCOTT.—I cannot remember whether the chanter has the major third or minor third?

Mr. BLAIKLEY.—It is between the two, but rather nearer the minor third than the major.

The CHAIRMAN.—There is a great vagueness about that third! We must again thank Mr. Blaikley for giving us so valuable a paper, which will be worth reading.