THE HINDU MUSICAL SCALE

THE TWENTY-TWO SHRUTEES

BY

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(Retired Deputy Collector)

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1910.
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<td></td>
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<td>F</td>
<td>Fa</td>
<td></td>
</tr>
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<td>G</td>
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<td>नि. मधु</td>
<td>B</td>
<td>Si</td>
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</table>

| अ. को. अद्वीयमल | f | Double flat |
| को. कोमल | f | Flat |
| त. ती. तततरस | ss | Double sharp |
| ति. तीन | s | Sharp |
INTRODUCTION.

The work accomplished by Mr. Deval, it would naturally be an exaggeration to say, marks an epoch in the history of Indian Music. As he tells us, many treatises have already been written on the subject, but those, who have heard Indian Music and who have sufficiently keen musical perception to appreciate the smoothness and beauty of the intervals used, must have laid down some of those books after reading them with a feeling of bewilderment. If Mr. Deval's results are accepted, the Indian scale which is several thousand years old will stand out as the most perfect example of a natural untempered scale.

That Mr. Deval's 22 Shrutiś are the correct ones may in the first place be presumed from the fact that he has studied the latest European literature on the subject of the formation of scales, and has spent eight years in testing the notes used by various singers in order to ascertain the exact intervals which the singers endeavour to produce. As he tells us, he has been guided by the principle laid down by old Indian writers on Music, that the simplest ratios are always the best.

Secondly it will be found that, although Mr. Deval did not test his Shrutiś by major and minor thirds, they will stand the test. One of the principal intervals, C to E, is awkwardly broken by Amavadi, or imperfect consonance. Indian singers are quite familiar with thirds, and in their more elaborate efforts make frequent use of arpeggio forms with thirds, fifths and other harmonic intervals; it may be inferred that the relationships by thirds which exist among the 22 Shrutiś are not by any means accidental.

<table>
<thead>
<tr>
<th>The major thirds</th>
<th>The minor thirds</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Sa : ti, ga.</td>
<td>(1) Sa : ti, ga.</td>
</tr>
<tr>
<td>(2) K. ri : K. ma.</td>
<td>(2) a. k. ri : ti, ga.</td>
</tr>
<tr>
<td>(3) ti. ri : ti, m.</td>
<td>(3) m. ri : k. ma.</td>
</tr>
<tr>
<td>(4) K. ga : pa.</td>
<td>(4) k. ga : t. t. ma.</td>
</tr>
<tr>
<td>(6) K. ma : m. dha.</td>
<td>(6) m. ma : k. dha.</td>
</tr>
<tr>
<td>(7) t.t. ma : k. ni.</td>
<td>(7) ti. ma : ti, dha.</td>
</tr>
<tr>
<td>(8) pa : ti, ni.</td>
<td>(8) pa : k. ni.</td>
</tr>
<tr>
<td>(9) K. dha : Sa'.</td>
<td>(9) ak. dha : ti, ni.</td>
</tr>
<tr>
<td>(10) m. dha : ak. ri.</td>
<td>(10) m. dha : sa'.</td>
</tr>
<tr>
<td>(11) ak. ni : m. ni.</td>
<td>(11) ak. ni : k. ni.</td>
</tr>
<tr>
<td>(12) k. ni : ti ri.</td>
<td>(12) ti. ni : ti, ri.</td>
</tr>
</tbody>
</table>
Thirdly, a test may be applied based on the three Gramas. This subject is not well understood at the present day. So far as I can gather, the ancient system permitted of two kinds of Modulation, modulation from one mode or Raga to another using in each Raga certain well defined combinations of the Tivra and Komal notes of the scale as essential notes and certain others as auxiliary notes or "Murchchhanas," and modulation from one Grama to another. The Shadj Grama is referred to Panchama or G as the fundamental note, the Madhyam Grama to Komal Madhyam or F and the Gandhara Grama to Tivra Gandhara or E. Mr. Deval's Atikomal Rishab or C sharp, would in the Shadj Grama correspond nearly with Tivra Madhyam.† The intervals used in the Gandhara and Madhyam Gramas have been described by various authors. The first has its semi-tones between the 2nd and 3rd and 5th and 6th and therefore corresponds with E, F sharp, G, A, B, C, D, E. The "Madhya Dhaivat" of 400 vibrations appears to be required in this Grama. The Madhyam Grama in which a scale like our just major scale is used, requires Madhya Rishab, Madhya Dhaivat and Atikomal Nishad; I ascertained from Mr. Deval's monochord that Prof. Abdul Karem actually used these notes in the Bhimpalas Raga which is evidently set in the Madhyam Grama. Lastly it must be noted that the tenth note, Atikomal Madhyam, is the familiar dominant seventh.† As one would expect it is only used in conjunction with E or Tivra Gandhara. Of the remaining notes some are said to be used only as "Murchchhanas" or auxiliary notes; in this connection it is to

* Perhaps madhya dhaivat is used in this Grama. This note with ak. ri. and ti. Ga, forms a major chord.

† In several Ragas ti. ma. (F sharp) and K. dha. (A flat) are found together. The former note has been tested and cannot be mistaken for any other such as G flat. This, together with the tonic and dominant pedal and the progression of melody used, appears to show that the "augmented sixth" is known to Indian Music.

be remembered that in a Murchchhana, the quarter tone involved is frequently combined in a peculiar kind of ornamentation with its fifth. It follows that each note used as a Murchchhana must have its fifth amongst the remaining Shrutis.

In this way Atikomal Rishab which, as I have said, may be an essential note in the Shadj Grama, but which is generally used as a Murchchhana upon the note Sa, has its corresponding note "Atikomal Dhaivat." If the notes of the Tivra and Komal scales, those I have mentioned as being traceable to the Gramas, and their corresponding fifths, are eliminated, there remain Tivratar Madhyam of 345 3/5 vibrations and Tivratar Nishad of 455 5/8. These notes appear to be actually used as essential notes in combination with "Madhya Dhaivat" and "Tivra Gandhara" in one Raga. This involves the use of harmony which is unknown to European Music. Tivratar Madhyam also corresponds with G flat in its harmony with Komal Gandhara and Komal Nishad.

Mr. Deval's 22 Shrutis appear to throw considerable light on the question of the constitution of the Ancient Greek Modes and will, I have no doubt, prove of the highest interest to European Scientists. In his book on the "Sensations of Tone," Prof. Helmholtz expresses doubt whether the Greek Modes were built up from the relations of F or those of G, and he suggests that they may possibly have been built up from both. If the Komal notes of Mr. Deval's scale are taken with Sa and Pa, as in the scale which he calls the Indian Diatonic Minor Scale, a scale is obtained which is in all probability identical with the Dorian Mode. If the identity is accepted, it follows (1) that B flat is the fifth above E flat and is a relation of G, 2) that A flat is the fifth above D flat and is a relation of F. It also follows that in the ancient scales until the time of Pythagoras, tuning exclusively by fifths or thirds was unknown, the simplest intervals, which are obtained by fifths and thirds combined, being used.
It is only in a system like the European, where transposition from one fixed key to another, and extensive modulation is practised, that tuning by a long series of fifths, tempered or otherwise, is likely to lead to anything but confusion. The Indian Tivra scale substitutes F sharp for F and the fifth above, D for the A in our major scale, thus producing the smoothest and most harmonious scale possible, one in which every note is in primary or secondary harmony with G. This scale appears to be identical with Syntono-Lydian Mode. As regards the question of tonality, writers who accuse Indian Music of being deficient in that respect are probably not aware that it is an almost invariable rule for Indian Ragas to be accompanied by a pedal bass of the tonic and its fifth. The effect is certainly to suggest harmonies which lead to a full close on the tonic in most Ragas and in some perhaps to a half close on the same chord.

Indian Musicians owe a great debt of gratitude to Mr. Deval, for now that the Shruties are known, it will be possible to construct harmoniums which will be in tune with Indian Music. The tempered harmoniums now in use which have a painful effect upon Indian ears will then be discarded. I have no doubt that with the advent of properly constructed keyed instruments, Indian Music will enter upon a new era of progress and development, possibly in the direction of harmony, for harmony is already extensively practised in the form of irregular Arpeggios. This progress will be hastened by the invention of a simple musical notation; and for that purpose also Mr. Deval's researches will be of the utmost value.


E. CLEMENTS.

* The 3rd being omitted the over-tones would strongly suggest a major chord. Mr. Deval has promised to undertake a careful examination of the Ragas. Such an examination ought to set at rest many doubtful points which suggest themselves in the present state of knowledge on the subject.

PREFACE.

Two years ago I published a small brochure entitled "Music East and West" dealing mainly with the scientific value of the Hindu musical scale and the question of "Shruties." But further study of the subject has enabled me to state more fully my humble views and hence the present pamphlet. I read specially Capt. Day's Book on "Music of Southern India" which was suggested to me by Sir J. W. Muir Mackenzie, the late Revenue Member of the Government of Bombay. He has a fine ear for Music. About 3 years ago I had an opportunity of explaining the subject to Sir J. W. Muir Mackenzie, when I laid before him my views, and practically demonstrated them with the help of Professor Abdur Kareem, an artist of great renown on this side of India. I also perused with great interest and profit the late Mr. A. J. Ellis' paper on the "Musical Scales of the World." Besides the valuable light thrown on the subject by these treatises, I had also much and invaluable enlightenment from Helmoltz's "Sensations of Tone," a masterly work on the Science of Music. The perusal of these and other works has served to strengthen the views previously held by me. The tables of Scales in the present brochure are almost entirely worked out afresh, and in some respects differ from those in the old pamphlet. In that work I had touched upon the question of Shrutes so far only as the Diatonic Scale of seven notes was concerned. In this brochure, I have arrived at a probable solution of the whole question of 22 Shrutes. The paper read in the Kirloskar Sangit Theatre on the Shrutes is incorporated in this pamphlet.

It should be remembered while reading this pamphlet that there are two kinds of tones—the tones of the natural scale
and those of the tempered scale. According to Blaserna the vibrations of these notes are as follows:

<table>
<thead>
<tr>
<th>Natural Scale or Just Major.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
</tr>
<tr>
<td>240, 276, 300, 320, 360, 405*, 450, 480.</td>
</tr>
</tbody>
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Tempered Scale.

240, 269, 302, 320, 359, 403, 453, 480.

It will thus be seen that the above two scales are quite different. When a European repeats the seven notes of the Modulator, Dho, (d); Ray, (r);* Me, (m); Fah, (f); Soh, (s); Lah, (l); Te, (t); Dho, (d); he necessarily refers to the notes of the tempered scale, which is now universally used in Europe in vocal as well as in instrumental music. The Hindoo Musician, who repeats the seven notes of the natural scale, refers to the natural scale which is given above. The notes in the natural scale are indicated by the letters C, D, E, &c., as has been done in Scientific Books, and not by the usual small letter Sofia notation to prevent ambiguity and confusion. I am, however, for the present concerned with the notes of the Hindoo Music and as such with the notes of the natural scale only, noted above.

The sharp and flat notes: — The sharp and flat notes of the tempered scale are the result of the sub-division of the interval between any two principal notes, into aliquot parts or equal divisions. Such is not the case with Hindoo Music.

The interval between C and D or between 240 and 270 vibrations or the length of wire between 32" and 36" is divided into 4 parts which, as measured by Ellis's cents, are not equal parts, but 70.42, 70, 22 cents respectively. The notes making up these intervals are called ज़, क़, क, रँ, मः, क़, नीँ, क़. The Indian word Komal must not be confused with.

* Blaserna gives 400 as the vibrations of A, whereas our A is of 405 vibrations, which is exactly the Panchama or the 5th of D, vibrations 270.
Indian Public. Not only this, but Mr. Clements has suggested to me that there is a branch of Indian Music which requires scientific and systematic treatment on similar lines. He has convinced me that without the development of this latter branch, the present attempt will be incomplete. I allude to the composition of Indian Rag's and Ragini's and especially to their notation, a subject, which I mean to take up as soon as I can.

SANGLI, 29-10-1916. K. B. DEVAL.

THE HINDU MUSICAL SCALE AND THE 22 SHRUTEES.

BY

Mr. K. B. Deval.
(Retired Deputy Collector.)

For more than the last eighty years, several attempts have been made to determine the Hindu Musical Scale with mathematical precision, by Indian and European scholars. But hitherto they have not been crowned with success; the solutions arrived at do not satisfy the tests of reason. Neither do they agree with conclusions noted by Sanskrit writers on Hindu Music. Hence it is that I propose to lay before the public a few thoughts about the Hindu Musical Scale and the lines of its development and progress. It might be stated here at the outset that the Hindu Musical Scale dates as far back as the Brahman Period which is calculated, according to modern researches, to extend from 2500 B.C. to 1400 B.C. It is possible that further researches might modify this date or might, perhaps, carry it still farther back. But we may be certain that our Scale dates farther back than the Greek Scale which is acknowledged to be the parent of modern European Scales. Capt. Day in his "Music of Southern India" observes:—"The Historian Strabo shows that the Greek influence extended to India, and also that Greek musicians of a certain school attributed the greater part of the science of music to India." The antiquity of the Scale apart, the most important point to be noted about it is that it is formed in consonance with the laws of the constitution of musical sound. It is a progressive Scale and the lines of its progress are laid down in old Sanskrit works on Hindu Music. The ancient sages of India, with their austere methods of study, meditating for years together in the quiet and tranquil recesses of nature undisturbed by the bustle of human habi-
tations, have preserved the results of their labours in their precious works, which excite, even to-day, the wonder and admiration of the cultured world. In recent times the attention of educated Indians turned to this Art of Arts, and men like the late Mr. Kunte, Messrs. Pingale and Sahasrabuddhe, Mr. Banhatti, Raja Surendra Mohun Tagore, Mr. Chinamswami Muddir, have written copiously on Hindu Music. But difficult as the subject is, several points have been enshrined in mystery e.g. the Shrutis. In some of these recent publications there appear misinterpretations of shlokas from the Sanskrit works. Hence they have given rise to a number of wrong notions about the Hindu Musical Scale, and consequently about the value of Hindu Music, not only among Indians but among scholars of the West. European writers on Hindu Music e.g. Capt. Willard ("Music of Hindustan"—a paper sent to the Society of Arts in 1834), Sir William Jones ("On Musical Scales"), Mr. Bosanquet ("On the Royal Society of Arts in London in 1877 on the Hindu Division of the Octave"), Mr. Patterson, Captain Day ("Music of Southern India"), Mr. J. A. Ellis ("On the Musical Scales of the World"), have come to hold erroneous views about the theory of the Hindu Musical Scale. This might be due partly to their ignorance of the Sanskrit works on Music, partly to the erroneous information supplied to them by recent publications, partly to the assumption that the Hindus must have followed a system similar to the equal temperament system at present in vogue in Europe. In 1883, the late Mr. J. A. Ellis, the distinguished English physicist, scientist, and translator and editor of Helmholtz's "Sensations of Tone", in his paper on "the Musical Scales of the World", after comparing and examining the Scales of the various nations among them the Hindu Musical Scale also—came to the following conclusion:

"The Musical Scale is not 'one', not 'natural', nor even founded necessarily on the laws of the constitution of Musical sound so beautifully worked out by Helmholtz, but very diverse, very artificial, and very capricious."

This I humbly submit cannot be said at least of the Hindu Musical Scale, as will be seen from the following. Now as observed by Professor Pietro Biaserna, of the Royal University of Rome, in his valuable treatise on the "Theory of Sound in its Relation to Music", by a musical scale is meant "the collection of all the notes comprised between the fundamental note and its octave, which succeed each other and are intended to succeed each other with a certain pre-established regularity." "The musical scale is always the product of the musical activity of a nation extending over a number of centuries." Hence to allow such wrong impressions about the Hindu Musical Scale to stand permanently on record and to suffer them to prejudice the minds of Western and Oriental Scholars as to the rank which the Hindu Musical Scale should take in the musical scales of the world, is neither just nor reasonable when there exists abundant evidence to disprove the above allegations. To elucidate all the difficult points of so difficult and scientific a subject as Music requires an amount of labour, energy, and talent which is given to but a few; it is a stupendous task, and personally I feel it quite hazardous on my part to attempt to undertake it. But approaching the subject with the humility and diffidence of a student, I have pursued my attempts hitherto and lay before the public the results of my humble labours.

2. It would be proper to state at the outset the laws of the constitution of musical sound which the ancient Sanskrit authors observed in their works on Hindu Music. In order to make this point quite clear, I place in juxtaposition the laws observed by Sanskrit writers and those followed by modern scientists of renown.
Both make a clear distinction between Sound and Musical Sound.

1. Sound.

European Scientists.

(a) Sound in our apprehension is that which is heard and therefore our only means of recognizing its existence is through the sensation on our ear. The auditory nerve alone can perceive sound.

(Holmes' Vocal Physiology-Ed. 1900-p. 52).

(b) Sound on the other hand is produced in our ears and is therefore subjective; but vibration is objective. It exists in sounding bodies independently of the listener. To a deaf man the vibration exists but the sound does not. Sound is the result of vibrations.*

Blaserna p. 27.

Authors on Aryan Music.

(a) सुनि (or मुद्र) सूति=to hear आवस्थणाच्छ एव कृत्तम्।

(b) अत्यधिकारण वायुमित्राः व्रतिविशेषः.

(c) शमतिक्रिया-विपर्ययः संग्रहणां कृत्तम् नृत्य-भाषणः सा कृत्तम्।

(d) सूति=संग्रहणां कृत्तम्।

May be translated as follows:

(a) + (b) Any sound which is heard by the ear is a shruti and is the product of vibration.

(c) + (d) A shruti and sound are one and the same and are perceived because the ear hears them.

Blaserna p. 165.


(a) Musical sound strikes us as being even, smooth and melodious like the tones of all musical instruments. Holmes p. 61.

(b) A note not accompanied by its harmonics may sometimes be sweet, but it is always thin and poor and therefore but little musical.

(c) In order that a sound may acquire a musical character, it must satisfy the essential condition of being agreeable to the ear.

Blaserna p. 74.

3. Harmonics.

Harmonics defined.

Strings in vibrating do not only swing as a whole but have also several secondary motions, each of which produces a sound proper to itself. A string, when struck, vibrates first in its entire length, secondly in two segments; thirdly in three; fourthly in four, and so on. All of these motions are simultaneous and the sounds proceeding from them are blended into one note. The lowest note is the loudest and is called the fundamental or prime tone, and the others are called over-tones, upper partial tones or harmonics.

In Sanskrit, Harmonics are called अवन्तुनामकानातः:

(a) गुरुन्तुनामकानातः विपर्ययः

(b) अवन्तुनामकानातः भग्नार्दतः विपर्ययः

(c) राजन्यार्दतः भग्नार्दतः

Holmes p. 69.

*So does शब्द (vibration) exist to a deaf man and शृष्टि (sound) is the result of 'रुक्तम्'.

Authors on Aryan Music.

(a) अत्यधिकारण अथवा अन्धुत्तमाकालः

(b) अथवा अन्धुत्तमाकालः

(c) अथवा अन्धुत्तमाकालः

(d) अथवा अन्धुत्तमाकालः
European Scientists.

Authors on Aryan Music.

The above Sanskrit piece marked (c) translated by Sir W. Jones runs as follows:

\[ \times \times \text{Nārada sat watching from time to} \text{ time his large Vṛttā (sonometre or monochord) which by the impulse of breeze, yielded notes that pierced successively the regions of his ear, and proceeded by} \]

\[ \text{musical intervals}. \]


dingale's treatise, p. 261.

It need hardly be noted here that the great sage Nārada perceived these Musical intervals, (otherwise called harmonics) as arising from the whole length of the wire set free to vibrate on its own account and creating natural nodes and ventral segments as distinguished from artificial nodes and segments which it is necessary to produce (as will be seen in the sequel) in the construction of the Musical Scale.

\* Nārada's Vṛttā is called Śrṅgā in Page 23 of "Hindu Music" Gayan Samaj.

Vṛttā is the name given to the śrṅgā of Nārada in the stanza quoted here.

Here we have in the clear poetic way of Magha, noted down a fact which, ought to arrest our attention, Nārada is descending from the heaven to the earth and the wind strikes his big lute the Mahāti. He was observing his instrument with the Murchansa of the several Gramas displayed or unfolded by the several Śrṅgas (upper partial tones) each showing on the string its distinct successive ventral segments, Sir William Jones seems to have under- stood the word Śrṅgas in the ordinary meaning of ear and not as the primary tone going to build up the secondary or upper partial or over tones. He interprets Mandala to mean regions or more scientifically, the encircling channels (of the ear). According to him the various Śrṅgas pierced the various recep-
European Scientists.

But if the string be touched in the middle, a tone which is double in pitch, which practical musicians call the octave of the fundamental note, is obtained. The string in this case vibrates in two parts in such a way that the point touched remains at rest. This fixed point is called a node of the vibrating string and has been produced artificially by touching the string at the point indicated. Successively higher and higher notes can be obtained by the string by touching it at a third, a fourth, a fifth of its length, etc. etc.

(Blaserna, Chapter I, pages 11-14).

By the figures given in the margin Blaserna has shown the different modes of vibration which a string assumes in different cases when it vibrates as a whole or into 2, 3, 4 &c. parts. In the first case no node is formed, in the others we have one, two, three, &c. nodes. The parts of the string between the nodes which contain these points of maximum movements are called ventral segments. This is what we have in practice of Maghla.

Authors on Aryan Music.

are heard when the whole string resting on two fixed bridges is made to vibrate. He warns musicians to always test the correctness of their notes, whenever possible, by referring them to these śārūṃ harmonies.

ECHO—The best understood of all the cases of reflection is that which is called ECHO.

—Blaserna, page 43.

The reflection of sound has been utilized in various ways. Nature and art have combined to solve some problems not unknown in history. The celebrated "ear of Dionysius" is well known; it is a sort of hole excavated in the rocks near Syracuse where the least sound is transformed into a deafening roar. Similar phenomena are often met with under the large arches of bridges, viaducts, &c. &c.

Sympathetic Resonance.

Experiment shows that whenever a body vibrates, other bodies placed near it, are able to enter into a state of vibration on this condition only that such bodies shall be capable by themselves of producing the same note.

Blaserna, Ch. II, p. 49.

What is the limit of audible sounds? Does our ear perceive as a note any number of vibrations.

According to Sanskrit writers there are five divisions of sound.
whatever or is our perception confined between certain limits? Twenty or twenty-five vibrations just take place per second in order to produce appreciable note. The notes that are too low are badly heard and those that are too high are unpleasant.

Blaserna, pp. 66-67.

The well-known voice of a single singer embraces about two octaves. In the case of a woman a little more.

8. Laws of the vibrations of strings and of artificially produced harmonics.

Blaserna, pp. 71-72.

(1) When the whole string vibrates in one vibration, it gives its lowest note which is called the fundamental note.

If the whole string be touched in the middle with a finger, a higher note is obtained, which practical musicians call the octave of the fundamental note.

(2) If the string be divided by touching it with a finger or a feather into two, three, four, &c., parts, higher and higher notes are obtained which form that which is called "En-harmonic" series.

The whole vibrating length of the string resting on the two fixed bridges (तंड) gives a note (रहड़) which in English is called the fundamental note.

\[
\text{रहड़: पद्म: हियुप्युप्य:} \\
\text{र. वि. वि. 1 आर्य 32.} \\
\text{सच्चान्तान्तर: पद्म: – हियुप्युप्य: पद्म: हियुप्युप्य:} \\
\text{A note double of the fundamental is obtained, if the wire is halved.} \\
\]

Blaserna. Chap. 5 sec. 2.


It may be established as one of the fundamental principles of our music that the ear can endure notes, be they simultaneous or successive, on this condition—viz: that they should bear simple ratios to each other in respect of the number of their vibrations per second, that is to say, that the ratio of the number of vibrations per second of the notes should be expressed by low numbers.

Blaserna. Chap. 5 sec. 2.
Blaserna divides consonant intervals or simple ratios into 4 groups.
1. Unison or octave चुळूं संध्याक म्हणून नावे अज वि. २१. २. Perfectly consonant संध्याक.
3. Consonant संध्याक.
4. Dissonant विठ्ठाक.


When two notes not exactly of the same pitch and bearing intricate ratios are sounded together (a new phenomenon is observed known by the name of beats) a sound is obtained of varying loudness, both strong and of feeble, and very marked jerks or shocks are perceived. These shocks are the beats &c. &c.

If one of the two notes be slightly altered unpleasant beats are heard and they "spoil the harmony."

Blaserna Chapt. V, Sec. 4, 5 and 6.

11. Resultant notes or difference notes.

Blaserna in sec. 6 Chapter 5.

Whenever any two notes bearing simple ratios are combined, besides these two notes a low note is very clearly heard (i.e., when two notes making 200 and 230 vibrations per second are sounded, a third note corresponding to 50 vibrations per second is heard. This number is the 4th part of 200 or the half of the half).

If translated it is as follows—The first string should be so tuned as to give the fundamental note. The second to give its 5th, the 3rd to give the octave, and the 4th to give F, the fourth of the octave. Now supposing the fundamental note gives 24 vibrations per second, we find out the following vibrational values of the 4 notes combined.

"If then several notes be combined" observes Blaserna "it is not enough to select those which by themselves will give an agreeable harmony; it is necessary further to examine the resultant notes and to see how these will behave in relation to the combined notes."

Now if we find out the values of the resultant notes they are as noted in the margin.
European Scientists.

The discovery of these resultant notes was made towards the middle of the 18th century and is generally attributed to the celebrated violinist Tartini.

Authors on Aryan Music.

This very same principle has all along been strictly observed both by the celebrated Rishi Narada (who is called the father of music) during the Yoke period and also by instrumentists and composers of subsequent periods.

× How the first two resultant notes form into the lower octave of the fundamental note $\frac{4}{3} = 12$ how the 3rd note vis: of 32 vibrational value forms into lower octave of $\frac{5}{4} = 32$ and how these 3 notes support the original 4 notes and how they thus contribute to the harmony of the whole instrument, may be more easily heard and enjoyed than described.

The next most simple ratio that can be imagined after union is that of 1 to 2. This is the ratio called that of the octave.

3. From the foregoing comparison of the fundamental laws of the constitution of musical sound, adopted by modern scientists, and those observed by our old Sanskrit writers, it will be clear that in constructing their musical scale the Aryan authors proceeded on scientific lines. How from these laws the Diatonic scale of seven notes, or the अरसत्ताक was formulated may be noted below. It may be stated that the rule of perfect concord and of harmonics was strictly observed in the construction of the musical scale. An explanation of the ordinary terminology in Sanskrit musical works would help towards understanding the subject: नेन=fixed bridge; moveable fret=सारित्त; श्रवणिक=unison or the relation between notes bearing the ratio of an octave; ऋकबीकक=perfect concord, ratio of 2:3, अकबीकक=imperfect concord, ratio of 3:4 or 4:5; वकबीकक=dissonance. They lay down that the rule of perfect concord should be observed strictly in forming musical scales. The lengths which will be given for the several notes in the Diatonic scale below, are those of the wire of the Diatonic, whose length, I take to be 36 inches, each inch being further divided into 20 subdivisions, which I call lines. I also take 240 vibrations for the fundamental note वह. In the Diatonic are two strings or wires, resting on two fixed bridges, one at each end. When experiments are to be made, we have to tune one string to give out a note which may be called the fundamental note. The other string is to be tuned so that it may be in full unison with the first. When the two strings are thus tuned, then the moveable bridge is to be moved about for producing the required notes. Its height must be such as to leave no distance whatsoever between the string and the bridge, yet not pressing the string upward. One of the strings is to be left free to vibrate on its whole length, giving the fundamental note, while the different notes required are to be produced on the other. On moving the bridge to the distance required for producing a note, the string is to be pressed very lightly to the edge of the bridge with the finger-nail, so as not to increase the tension in the least. Then the exact note will be produced on sounding the string. To get the exact note on the given length, it is necessary that there should not be any disturbing element such as increased tension caused by pressing the string downward to the bridge. This depends on the accuracy of the instrument.

How the positions and vibrations of the 7 notes of the Diatonic Scale and the octave, have been settled with mathematical precision is shown below.
\( \text{ Rule (3) The pitch of a note or its vibrations are inversely proportional to the length of the wire.} \)

This rule is a legitimate inference from the above two rules. Rule (1) permits us to take any length for the Fundamental Note (F.N.) and according to Rule (2) if the length is halved the pitch is doubled; and if the length is doubled the pitch or the number of vibrations is halved. If therefore \( \frac{2}{3} \) length is taken the pitch or the number of vibrations produced will be troubled. Or by generalization:

\[ \text{ Rule (4) The pitch varies inversely as the length and vice versa.} \]

The above four rules may therefore be put in the form of a simple Formula for convenience of working and ready reference.

Let \( V_n \) = Vibrations or pitch of the note on wire \( t \) inches long. \( w \) = The vibrations or pitch of \( \text{ C} (c_1) \) the F.N., here \( = 240 \).

\[ l = \text{The length of the wire of the F.N. here} = 36 \text{ Inches} = 36''. \]

Then:

\[ V_n \times l_n = u \times l \quad \text{(A)} \]
\[ V_n = u \times \frac{l}{l} \quad \text{(B)} \]
\[ 2 = u \times \frac{l}{V_n} \quad \text{(C)} \]

therefore if \( V_n = 2u \)

\[ l_n = \frac{l}{2} \quad \text{(D)} \]

\[ \text{ (F).} \]

\[ \text{ Rule (5) The note } \text{ (For the fourth note) is produced at the middle of the Fundamental Note and its octave.} \]
The note $\pi$ is therefore produced at half the length of $\pi_1$ ($c_1$) and $\pi_2$ ($c_2$) or at $\frac{1}{2} (36'' + 18'') = 27''$. In other words, the notes of the wire 27" or 27" inches of the executive part of the wire will give out the 4th note or $\pi$ (F) and by Rule (4), formula (B) the pitch or vibrations of $\pi$ (F) are equal to 320.

The formula (B) is:

$$V_1 = \frac{u}{l}; \quad \text{Here} \ u = 240, \ l = 36 \ & l_1 = 27$$

$$V_2 = 240 \times \frac{36}{27} = 320 = \text{Vibrations of} \ \pi$$

And formula (C) is:

$$l_2 = u \times \frac{l}{V_2}; \quad l_2 = 240 \times \frac{320}{4} = l = \frac{3}{4} \times 36$$

or the length of $\pi$ is $\frac{3}{4}$ of the length of the F.N. and the vibrations of $\pi$ are $\frac{3}{4}$ of the F.N. and it may be laid down

**Rule (6)** That the length of the wire of $\pi$ (F) or the 4th note is $\frac{3}{4}$ of that of the Fundamental Note and the vibrations of $\pi$ (F) are $\frac{3}{4}$ of the vibrations of the Fundamental Note $\pi_1$ ($c_1$).

$\pi$ (G).

**Rule (7)** The fifth or $\pi$ ($c_1$) note is produced on $\frac{2}{3}$ or $\frac{3}{4}$ of whole length of the wire. The former note is one octave higher than the latter.

The length of the wire is 36". Therefore a length of 12" or 24" will give the fifth note $\Pi$ (G). But we want the length between 18" and 30"—the two limits of the octave. Therefore the length 24" is that which we require and it will give out the note $\pi$ (G).

Let us apply the formulae (B) and (C) to the case of $\pi$ (G).

$$V_2 = \frac{u}{l_2}; \quad \text{Substitute the values} \ u = 240, \ l = 36 \ & l_2 = 24$$

$$\therefore \ V_2 = \frac{240 \times 36}{24} = 360 = \text{Vibrations of} \ \pi \ (G)$$

$$\therefore \ u = \frac{360 \times 3}{24} = \text{u}$$

or the Vibrations of $\pi$ (G) are $\frac{3}{4}$ of its $\pi_1$, or F.N.

and

$$l_2 = \frac{u}{V_2}; \quad (C)$$

or the length of $\pi$ is $\frac{3}{4}$ of its $\pi_1$ ($c_1$) or F.N.

These facts may be noted down under Rule (8) below:

**Rule (8)** The length of the wire of $\pi$ (G) or the fifth note is $\frac{3}{4}$ of that of $\pi_1$ ($c_1$) wire and its vibrations or pitch is $\frac{3}{4}$ of that of $\pi_1$ ($c_1$).

$\pi$ (D) and $\pi$ (A).

**Rule (9)** In the interval of a given octave, $\pi_1$ ($C_1$) with $\pi$ (G) and $\pi$ (F) with $\pi_2$ ($C_2$) form perfect concords; it may be noted that $\pi_1$ ($C_1$) with $\pi$ (F) and $\pi$ (G) with $\pi_2$ ($C_2$), the inverted interval, form imperfect concords.

This rule is very important and is made use of in finding out the lengths and vibrations of the other notes $\pi_1$ (D), $\pi$ (E), &c. &c.

According to Rule (1) any length may be said to give the fundamental note and its $\pi$ will be the 5th note from it. This $\pi$ or $\pi$ will form a perfect concords with it. This gives us the following consonant notes.

<table>
<thead>
<tr>
<th>F. N. $\pi_1$ ($C_1$)</th>
<th>Consonant note $\pi$ (A) or $\pi$ (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\pi_2$ ($C_2$)</td>
<td>$\pi$ G</td>
</tr>
<tr>
<td>$\pi_2$ ($E_2$)</td>
<td>$\pi$ G</td>
</tr>
<tr>
<td>$\pi_2$ ($G_2$)</td>
<td>$\pi$ G or $\pi$ G</td>
</tr>
</tbody>
</table>

* As I proceed to show, $\pi_2$ ($E_2$) is not a perfect concord with $\pi$ (A); nor is $\pi_2$ ($F_2$) with $\pi$ (B).
Let us take ī (C) itself as the starting or fundamental note, then its न्दिम or fifth will be त D in the higher octave which may be called ट्र D. Apply the formula (B).

\[ V_n = \frac{u}{l} \]

Here \( u = 360, l = 24 \) and \( l_n = \frac{3}{4} \times 24 = 18 \). Therefore the vibrations of ī V are \( 360 \times \frac{3}{4} = 540 \).

540 are the vibrations of ī, or ī (D) in the 2nd octave. Therefore the vibrations of ī in the first octave are \( \frac{3}{4} \times 540 = 270 \).

Rule (7). Substituting the values of \( u, l, \) and \( V_n \), we have

\[ l_n = \frac{3}{4} \times 240 = 180 \]

Vide Rule (2).

Formula (C) is

\[ V_n = u \frac{v}{l} \]

Substituting \( u = 240, l = 24 \) and \( V_n = 270 \), we have

\[ l_n = \frac{3}{4} \times 240 = 180 \]

Hence the length of ī is 281\(\frac{3}{4}\) and its pitch is 300.

Rule (13). If the vibrations of ī (E) be taken at 300 (and there is no reason for doing so), in place of 303\(\frac{3}{4}\) as obtained in Rule (2) above, then

\[ l_n = \frac{3}{4} \times \frac{300}{308} = 181\frac{3}{4} \]

Thus the length of ī is 281\(\frac{3}{4}\) and its pitch is 300.

The ī (E) obtained by the foregoing process has 303\(\frac{3}{4}\) vibrations and bears with the ī, Note a complicated ratio viz. 81 : 64. The ī (E) obtained as the fifth harmonic when reduced by two octaves has 300 vibrations and bears with the ī, Note the simple ratio of 5 : 4; and it sounds more consonant with it. It is clearly heard on the string (the fourth, giving ī or ī Note) of the Vina.

Sanskrit writers have adopted this in preference to the other. They tested their notes by harmonics; the author of रामचरितमानस clearly lays down: वैयक्तिकः निर्देशितमानसाधनस्य। रा. वि. चिन्ता 9 आँश 9 रीजन.

\(\text{न (A)}\) \& व (B).

The length of ī (A) is 21\(\frac{1}{4}\) and its vibrations are 405. Let us take ī as the fundamental note (Rule 1); then ī (E) or ī, त in 2nd octave becomes its न्दिम or the 5th note (Rule 9). Therefore its length is \( \frac{3}{4} \times 21\frac{1}{4} \) and vibrations \( \frac{3}{4} \times 405 \); but these are for ī. Therefore according to Rule (3) The length of ī is \( \frac{3}{4} \times \frac{3}{4} = 21\frac{1}{4} \)

\[ = \frac{3}{4} \times \frac{3}{4} \times \frac{3}{4} = 21\frac{1}{4} \]

and the vibrations of ī = \( \frac{3}{4} \times 405 = \frac{1215}{4} = 303 \).

\(\text{व (B)}\).

The length of ī is 28\(\frac{1}{4}\) and its vibrations 303\(\frac{3}{4}\) (Rule 12). If we take ī as the Fundamental note, then \(\text{व}\) becomes the न्दिम त fifth note; Therefore the length of ī is \( \frac{3}{4} \times 21\frac{1}{4} = 181\frac{3}{4} \) and the vibrations of ī = \( \frac{3}{4} \times 405 = 181\frac{3}{4} \).

Rule (13). If ī (E) is taken as the fundamental note, then \(\text{व}\) becomes the न्दिम the fifth in the same octave.

\[ 300 \times \frac{3}{4} = 450 = \text{the vibrations of} \text{व by Rule (8)}; \]

and the length is \( \frac{3}{4} \times 28\frac{1}{4} = \frac{3}{4} \times \frac{3}{4} \times \frac{3}{4} = 181\frac{3}{4} \).

The vibrations of \(\text{व}\) are 450

Notes and Summary.

1. The lengths and vibrations of ī, (C) and ī, (C) are directly derived from Rules 1-2-3 which are based on the directions distinctly laid down in old Sanskrit works on Music—रामचरितमानस, रामचरितमानस, रामचरितमानस, रामचरितमानस.
2. Rule 1 expresses the form of the formula the results of the above rules. The formulae which are derived from formula A are given below for the convenience of ready reference.

\[ V_n \times l_n = u \times l \]  
\[ V_n = \frac{l}{u} \]  
\[ l_n = \frac{u}{V_n} \]  
\[ l = \frac{1}{l_n} \]  

where \( V_n \) = Vibrations of the length \( l \) where \( u = \) Vibrations of length \( l \), which are respectively 240 and 36'.

The rules are not discoveries of new truths in the science of the theory of Music. But they prove that these truths were known to Sanskrit writers on Music several centuries ago.

3. Rule (5) gives the length of \( \alpha \) (\( F \)) the 4th note as prescribed by गणकिपिन्द. Rule (6) notes down the length and vibrational value of \( \alpha \) (\( F \)) as worked out from the rules.

4. Rule (7) determines the position of \( \beta \) (\( G \)), the 5th note, its length on the diatonic and its vibrations. Rule (8) notes down the length and vibrations of \( \beta \) (\( G \)) the fifth note in general in any octave.

The positions, length and vibrations of \( \alpha \), \( \beta \) (\( C \)), \( \gamma \) (\( F \)), \( \delta \) (\( G \)) and \( \varepsilon \) (\( C \)), the 4 principal notes which have consonance of the first order, are thus marked down, worked out and settled. It now remains to find out the same of the remaining notes viz. \( \delta \) (\( D \)), \( \beta \) (\( E \)), \( \gamma \) (\( A \)) and \( \psi \) (\( B \)). This is done by the rule of उपसर्गिन of the 5th note \( \eta \) (\( G \)) which may be called the rule of perfect concord.

5. Rule (9) describes in full the rule of perfect concord and how it may be used in finding out satisfactorily every thing required to be known of the remaining 4 notes—\( \beta \), \( \gamma \), \( \delta \) and \( \psi \).

6. Rules (10) and (11) show how the lengths and vibrations of \( \beta \) and \( \gamma \) may be found from those of \( \delta \) (\( G \)) by applying the rule of perfect concord.

7. Rule (12) and (13) show how the lengths of \( \gamma \) (\( E \)) and \( \delta \) (\( B \)) are determined, the first by imperfect concord with \( \alpha \) (\( C \)) and the second by perfect concord with \( \varepsilon \) (\( E \)).

8. The lengths and vibrational values of all the notes in an octave are thus found out, by means of rules distinctly laid down in old Sanskrit works on Hindu Music such as गणकिपिन्द, संगीतविकार and बंगला-रत्नाकार.

9. I give below Table A, the Diatonic Major Scale तिन त्रित्राममत्र नामक showing the number of Shrutoes assigned to each note; the number of vibrations, lengths of wire of the Diatonic Major Scale, the number of Mr. Ellis' cents, the musical intervals between any two consecutive notes of the scale, the ratios of each note with the fundamental note, and the English names of the intervals and notes:

10. Now on looking at this table it will be seen that there are three kinds of musical intervals viz. 8:9, 9:10 and 15:16. In the scale the interval 8:9 occurs three times, 9:10 occurs twice and 15:16 occurs twice. The seven intervals form two triads: the intervals between \( \alpha \) and \( \beta \), \( \beta \) and \( \gamma \), and \( \gamma \) and \( \delta \) forming the first triad; while those between \( \beta \) and \( \gamma \), \( \gamma \) and \( \delta \), and \( \delta \) and \( \varepsilon \), forming the second triad. Each interval of the first triad exactly allies with the corresponding interval of the second triad. The interval between \( \alpha \) and \( \beta \) (8:9) stands as a neutral zone between the two triads. It is interesting to see that these intervals are evenly distributed. The interval between \( \alpha \) and \( \beta \) (8:9) which is the largest, occurs between \( \alpha \) and \( \beta \) of the second triad. The smaller interval between \( \beta \) and \( \gamma \) (9:10) of the first triad also lies between \( \beta \) and \( \gamma \) of the second triad. The smallest interval 15:16, which lies between \( \beta \) and \( \gamma \) also appears between \( \beta \) and \( \gamma \) (octave) of the second triad. The total of Mr. Ellis' cents for these intervals is 1200.

11. Similarly we might note with interest the Diatonic Minor Scale (संगीतविकार नामक) shown in Table B given below. It consists of eight notes including the upper Octave, like the Major Scale तिन त्रित्राममत्र, as shown in Table A.

\[ \text{The assignment of Shrutoes in Column 2, to the different notes is based on the following Arya (अर्य):} \]

\[ \text{गणकिपिन्द (गणकिपिन्द):} \]

\[ \text{ए, अ, आ, आध, ए, ओ, ओध, एध.} \]

\[ \text{For the explanation of the word मत्र, I would draw the attention of the reader to Paragraphs 17 and 20.} \]

\[ \text{By dividing the interval between the fundamental note of value one (1) and its octave of double the value i.e. two (2), into 1200 cents, according to his method, Mr. Ellis has devised a system for measuring the various intervals. This system, into the details of which we need not go at present, has been used for testing the scales of the world. It would be gratifying to learn that the Hindu Musical scale stands this test of cents admirably.} \]
12. It will be seen from the Diatonic Major Scale (Table A) that the smallest interval is 15:16 that between ई and र, and र and र. This interval is used in forming our Chromatic Scale of twelve notes. Perhaps here a question may be asked as to why the particular interval of 15:16 is used in formulating the chromatic scale of twelve notes. To this question the simple answer is this. When we look at the seven musical intervals of the Diatonic Major Scale we find that of these seven, five are large intervals and two are the smallest, viz., those of 15:16 between ई and र, and र and र. Sanskrit writers have termed the musical scale as “a ladder” —सालखा (सालखा विधान), विधान. They have formed out of this Diatonic Major Scale of seven notes a Chromatic Scale of twelve notes by putting four more smaller notes or steps. They have also styled र, the fourth note or step of the Diatonic Scale, as कक्ष; this was the smallest step of the musical ladder. Now it is evident that in introducing minor notes the smaller ratios or intervals would have to be utilized. Thus we get a method for developing the Scale by introducing minor notes.

13. Proceeding thus, while forming our Chromatic Scale of twelve notes, the smallest interval 15:16 is introduced between the five notes of the Diatonic Scale having larger intervals viz. 8:9 and 9:10. The interval between ई and र is 8:9. This is the smallest step. An interval of 15:16 is introduced between these two notes. Thus obtained a third note called कक्ष with 240 vibrations, ई being of 240 vibrations. Now र stands to कक्ष in the ratio of 16:16 and कक्ष stands to र in the ratio of 16:16. Assigning Mr. Ellis’ cents to these intervals, we get for 15:16, 112 cents and for 128:135, 92 cents. The larger interval of 8:9 having 240 cents is thus split up into two smaller ones of 92 and 112 cents respectively, making a total of 204 cents. The same ratio 15:16 is again introduced in the second half of the scale between र and र. And the results are similar. In this manner we have got कक्ष and its corresponding संताने note (consonant) in the second half viz. र. र. Again similarly we divide the larger interval of 9:10 as before by the introduction of a smaller one of 15:16. Thus we get कक्ष of 288 vibrations, र being of 300 vibrations. The interval between र and कक्ष becomes 15:16, and has 112 cents; and that between कक्ष and र becomes 24:25 and has 70 cents. These two smaller intervals make up the 182 cents which was the number for the second larger interval of 9:10. Similarly we have introduced कक्ष between र and र with 432 vibrations and having a ratio of 15:16 with 112 cents. The interval between र and कक्ष and र is 24:25 with 70 cents. Thus we have in place of the seven notes of the Diatonic Scale, or eight including the upper octave, the following twelve notes of the Chromatic Scale viz. 1 र + 2 र + 2 र + 1 र + 1 र + 2 र + 2 र + 2 र + 1 र = 12. Between र and कक्ष which with र form the backbone of our scale, we insert a note called कक्ष. This note is the 5th harmonic of र and therefore forms a कक्ष with it. र and कक्ष are kept fixed and unchangeable...
### TABLE A.

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Names of Notes</th>
<th>Vibrations</th>
<th>Musical Interval</th>
<th>Its name</th>
<th>Ellis' cents</th>
<th>Ratio of each note with the Fundamental Note</th>
<th>Its name</th>
<th>Ellis' cents</th>
<th>Vibrating length of wire required for each Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>पद्म or C</td>
<td>240</td>
<td>8 : 9</td>
<td>Major 2nd</td>
<td>204</td>
<td></td>
<td></td>
<td></td>
<td>Inches-lines</td>
</tr>
<tr>
<td>2</td>
<td>कप्पण or D</td>
<td>270</td>
<td>9 : 10</td>
<td>Minor 2nd</td>
<td>182</td>
<td></td>
<td></td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>3</td>
<td>गोधर or E</td>
<td>300</td>
<td>15 : 16</td>
<td>Diatonic Semitone 112</td>
<td>320</td>
<td>Just Major 3rd; 5th Harmonic</td>
<td>386</td>
<td>28-16 lines</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>मध्यम or F</td>
<td>320</td>
<td>8 : 9</td>
<td>Major 3rd</td>
<td>204</td>
<td></td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>5</td>
<td>पंचम or G</td>
<td>360</td>
<td>8 : 9</td>
<td>Major 2nd</td>
<td>204</td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>6</td>
<td>पाँचम or A</td>
<td>405</td>
<td>9 : 10</td>
<td>Minor 2nd</td>
<td>189</td>
<td></td>
<td></td>
<td></td>
<td>21-6</td>
</tr>
<tr>
<td>7</td>
<td>निंद्र or B</td>
<td>450</td>
<td>15 : 16</td>
<td>Diatonic semitone 112</td>
<td>1200</td>
<td>Octave</td>
<td>1200</td>
<td>18</td>
<td>lines</td>
</tr>
</tbody>
</table>

### TABLE B.

<table>
<thead>
<tr>
<th>Serial No</th>
<th>Names of Notes</th>
<th>Vibrations</th>
<th>Musical Interval</th>
<th>Its name</th>
<th>Ellis' cents</th>
<th>Ratio of each note with the Fundamental Note</th>
<th>Its name</th>
<th>Ellis' cents</th>
<th>Vibrating length of wire required for each Note Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>पद्म or C</td>
<td>240</td>
<td>15 : 16</td>
<td>Diatonic semitone 112</td>
<td>320</td>
<td>Just Minor 3rd; 5th Harmonic</td>
<td>386</td>
<td>28-16 lines</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>को. कप्पण or D flat</td>
<td>256</td>
<td>8 : 9</td>
<td>Major 2nd</td>
<td>204</td>
<td></td>
<td></td>
<td></td>
<td>33-15</td>
</tr>
<tr>
<td>3</td>
<td>को. गोधर or E flat</td>
<td>288</td>
<td>9 : 10</td>
<td>Minor 2nd</td>
<td>182</td>
<td></td>
<td></td>
<td></td>
<td>30-0</td>
</tr>
<tr>
<td>4</td>
<td>को. मध्यम or F flat</td>
<td>320</td>
<td>8 : 9</td>
<td>Major 2nd</td>
<td>204</td>
<td></td>
<td></td>
<td></td>
<td>27-0</td>
</tr>
<tr>
<td>5</td>
<td>को. पंचम or G flat</td>
<td>360</td>
<td>15 : 16</td>
<td>Diatonic semitone 112</td>
<td>1200</td>
<td>Just Minor 7th</td>
<td>1018</td>
<td>20-0</td>
<td>lines</td>
</tr>
<tr>
<td>6</td>
<td>को. पाँचम or A flat</td>
<td>384</td>
<td>8 : 9</td>
<td>Major 2nd</td>
<td>182</td>
<td></td>
<td></td>
<td></td>
<td>22-10</td>
</tr>
<tr>
<td>7</td>
<td>को. निंद्र or B flat</td>
<td>432</td>
<td>9 : 10</td>
<td>Minor 2nd</td>
<td>182</td>
<td></td>
<td></td>
<td></td>
<td>20-0</td>
</tr>
<tr>
<td>8</td>
<td>पद्म or C'</td>
<td>480</td>
<td>15 : 16</td>
<td>Diatonic semitone 112</td>
<td>1200</td>
<td>Octave</td>
<td>1200</td>
<td>18</td>
<td>lines</td>
</tr>
<tr>
<td>Serial No</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>-----------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1</td>
<td>सत के अथ या C</td>
<td>240</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>112</td>
</tr>
<tr>
<td>2</td>
<td>कृष्ण की धारा D</td>
<td>358</td>
<td>128 : 135</td>
<td></td>
<td>92</td>
<td>8 : 9</td>
<td>Major 2nd-5th Harm</td>
<td>204</td>
<td>204</td>
</tr>
<tr>
<td>3</td>
<td>भक्ष्य के G</td>
<td>370</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>5 : 6</td>
<td>Just minor 3rd</td>
<td>316</td>
<td>316</td>
</tr>
<tr>
<td>4</td>
<td>भक्ष्य की धारा E</td>
<td>388</td>
<td>25 : 25</td>
<td>Diatonic semitone</td>
<td>70</td>
<td>4 : 4</td>
<td>Just major 3rd</td>
<td>336</td>
<td>336</td>
</tr>
<tr>
<td>5</td>
<td>कृष्ण की पद्म E</td>
<td>380</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>3 : 4</td>
<td>Just fourth</td>
<td>498</td>
<td>498</td>
</tr>
<tr>
<td>6</td>
<td>भक्ष्य की धारा पद्म E</td>
<td>380</td>
<td>128 : 135</td>
<td></td>
<td>72</td>
<td>32 : 46</td>
<td>Just tri-tone-6th Harm</td>
<td>590</td>
<td>590</td>
</tr>
<tr>
<td>7</td>
<td>माधुर्य के G</td>
<td>380</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>2 : 3</td>
<td>Just fifth</td>
<td>702</td>
<td>702</td>
</tr>
<tr>
<td>8</td>
<td>भक्ष्य की धारा A</td>
<td>384</td>
<td>15 : 15</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>5 : 8</td>
<td>Just minor 6th Pythagorean</td>
<td>814</td>
<td>814</td>
</tr>
<tr>
<td>9</td>
<td>कृष्ण की पद्म A</td>
<td>405</td>
<td>128 : 132</td>
<td></td>
<td>92</td>
<td>16 : 27</td>
<td>Major 6th</td>
<td>906</td>
<td>906</td>
</tr>
<tr>
<td>10</td>
<td>कृष्ण की पद्म B</td>
<td>432</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>112</td>
<td>5 : 9</td>
<td>Just minor 7th</td>
<td>1018</td>
<td>1018</td>
</tr>
<tr>
<td>11</td>
<td>भक्ष्य की धारा B</td>
<td>450</td>
<td>25 : 25</td>
<td>Diatonic semitone</td>
<td>182</td>
<td>8 : 15</td>
<td>Just major 7th</td>
<td>1088</td>
<td>1088</td>
</tr>
<tr>
<td>12</td>
<td>पद्म के G</td>
<td>480</td>
<td>15 : 16</td>
<td>Diatonic semitone</td>
<td>1200</td>
<td>1 : 2</td>
<td>Octave</td>
<td>1200</td>
<td>1200</td>
</tr>
</tbody>
</table>

The English names of the musical intervals in Col. 5 and of the ratios in Col. 8 are taken from the table of Harmonics on page 39 and the table of musical intervals on pages 163—166 of Helmholtz's "Sensations of Tone."
### Table D

(Referred to at page 9)

#### Indian Chromatic Scale of twenty-two

<table>
<thead>
<tr>
<th>No.</th>
<th>Name and kind of Shruti, बत्रि, जाति.</th>
<th>Name of notes.</th>
<th>Vibrations</th>
<th>Musical Interval lying between each pair of notes</th>
<th>It's name</th>
<th>Ellis' cents assigned to each interval</th>
<th>Ratio of each note with the Fundamental Note.</th>
<th>Its name</th>
<th>Ellis' cents assigned, Vibrating length of wire required for each note.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0)</td>
<td>धर्मी, गंभर्मा.</td>
<td>ष or G.</td>
<td>240</td>
<td>24 : 25 Small Semitone</td>
<td>70</td>
<td>24 : 25 Small semitone</td>
<td>70</td>
<td>34–11½</td>
<td>16–10</td>
</tr>
<tr>
<td>(1)</td>
<td>रामकिया, कलर्मा.</td>
<td>अ. की. द्र. Diff.</td>
<td>259</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2)</td>
<td>रामकिया, मन्नार.</td>
<td>को. अ. द्र. Diff.</td>
<td>256</td>
<td>24 : 25 Small Semitone</td>
<td>70</td>
<td>15 : 16 Diatonic or Just semitone</td>
<td>112</td>
<td>33–15</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td>रामकिया, भुजा.</td>
<td>उ. अ. द्र.</td>
<td>263</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32–8</td>
</tr>
<tr>
<td>(4)</td>
<td>लोचन, द्विवर्मा.</td>
<td>षी. था. दु.</td>
<td>270</td>
<td>80 : 81 Comma of Diatonic</td>
<td>22</td>
<td>8 : 9 Major second: 9 Harm</td>
<td>204</td>
<td>32–0</td>
<td></td>
</tr>
<tr>
<td>(6)</td>
<td>लोचन, भार्मा.</td>
<td>को. न. एक.</td>
<td>288</td>
<td>80 : 81 Comma of Diatonic</td>
<td>22</td>
<td>5 : 6 Just Minor Third</td>
<td>316</td>
<td>30–0</td>
<td></td>
</tr>
<tr>
<td>(7)</td>
<td>मात्रिक, भार्मा.</td>
<td>नी. ए.</td>
<td>300</td>
<td>24 : 25 Small Semitone</td>
<td>70</td>
<td>4 : 5 Just Major Third</td>
<td>386</td>
<td>28–16</td>
<td></td>
</tr>
<tr>
<td>(8)</td>
<td>मात्रिक, भार्मा.</td>
<td>नी. ए. एस.</td>
<td>303½</td>
<td>25 : 23 Comma of Diatonic</td>
<td>22</td>
<td>4 : 5 Pyth. Major Third</td>
<td>408</td>
<td>28–0</td>
<td></td>
</tr>
<tr>
<td>(9)</td>
<td>मात्रिक, भार्मा.</td>
<td>अ. की. न. फल.</td>
<td>315</td>
<td>63 : 64 Septal Comma</td>
<td>27</td>
<td>16 : 21 21st Harm, Sub F</td>
<td>471</td>
<td>28–8½</td>
<td></td>
</tr>
<tr>
<td>(10)</td>
<td>मात्रिक, भार्मा.</td>
<td>नी. फ.</td>
<td>320</td>
<td>128 : 135 Small Septal</td>
<td>92</td>
<td>3 : 4 Just and Pyth. Fourth</td>
<td>498</td>
<td>27–0</td>
<td></td>
</tr>
<tr>
<td>(11)</td>
<td>मात्रिक, भार्मा.</td>
<td>नी. फा.</td>
<td>337½</td>
<td>125 : 138 Gr.</td>
<td>42</td>
<td>12 : 45 Pluperfect Fourth</td>
<td>519</td>
<td>26–12</td>
<td></td>
</tr>
<tr>
<td>(12)</td>
<td>मात्रिक, भार्मा.</td>
<td>षी. फा.</td>
<td>345½</td>
<td>24 : 25 Small Semitone</td>
<td>70</td>
<td>25 : 36 Acute dim. Fifth</td>
<td>632</td>
<td>25–0</td>
<td></td>
</tr>
<tr>
<td>(13)</td>
<td>मात्रिक, भार्मा.</td>
<td>षी. ग.</td>
<td>360</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24–0</td>
<td></td>
</tr>
</tbody>
</table>

Note: The Sanskrit writers have assigned names to each one of the twenty-two Shrutis, indicating the particular emotion (or रा) excited by the particular note. As the twenty-two notes for the twenty-two Shrutis have been fixed in the above Table, it is easy to assign the names. It will be seen that along with the musical consonance in the notes, there is also a correspondence between the emotions excited by them. Experts like Prof. Abdul Kalam, a good singer of these notes, can actually reproduce these notes.

The following notes are also used by experts, अ. की. द्र. of 281½ vibrations, which is major third from षी. फा., and it has its corresponding षी. फा. of 421½ vibrations. The Shruti Kandhari as sung by Sahinuddin and Khayyam Kandhari; the Dagar and the Nusheja sang by Professor Aftabish and Gokhale brothers (who both are in the service of the Indian Chromatic Scale of twenty-two notes.}

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*Note: The text is in Sanskrit and English, discussing the Indian chromatic scale and its intervals, with notes on the emotions and consonance associated with each note.*
### Two Notes, or the Shrutee Scale.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name and kind of Shrutes, श्रुतेष्वर, श्रुति.</th>
<th>Name of notes.</th>
<th>Vibrations</th>
<th>Musical interval lying between each pair of Notes.</th>
<th>Its Name.</th>
<th>Ellis' cents assigned to each interval</th>
<th>Ratio of each note with the Fundamental Note.</th>
<th>Its name.</th>
<th>Ellis' cents assigned.</th>
<th>Vibrating length of wire required for each note.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>पंचम.</td>
<td>860</td>
<td>24 : 25</td>
<td>Small semitone.</td>
<td>70</td>
<td>2 : 3</td>
<td>Just Fifth; 3rd Harm.</td>
<td>702</td>
<td>24 - 0.</td>
</tr>
<tr>
<td>2</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>कार्त्ती.</td>
<td>375</td>
<td>120 : 125</td>
<td>Great Diatess.</td>
<td>42</td>
<td>16 : 25</td>
<td>Grave Sup-Fifth; 3H Harm.</td>
<td>722</td>
<td>23 - 2</td>
</tr>
<tr>
<td>3</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>अफ.</td>
<td>384</td>
<td>24 : 25</td>
<td>Small semitone.</td>
<td>70</td>
<td>5 : 8</td>
<td>Just Minor 6th.</td>
<td>814</td>
<td>22 - 10</td>
</tr>
<tr>
<td>4</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>400</td>
<td>80 : 81</td>
<td>Comma of Diatess.</td>
<td>22</td>
<td>3 : 5</td>
<td>Just Major 6th.</td>
<td>884</td>
<td>21 - 12</td>
</tr>
<tr>
<td>5</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>अफ.</td>
<td>405</td>
<td>243 : 256</td>
<td>Pyth, Limma.</td>
<td>90</td>
<td>16 : 27</td>
<td>Pyth, Major 6th; 7th Harm.</td>
<td>906</td>
<td>21 - 6</td>
</tr>
<tr>
<td>6</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>428</td>
<td>80 : 81</td>
<td>Comma of Diatess.</td>
<td>22</td>
<td>9 : 16</td>
<td>Just diminished 7th.</td>
<td>906</td>
<td>20 - 5</td>
</tr>
<tr>
<td>7</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>432</td>
<td>24 : 25</td>
<td>Small Limma.</td>
<td>70</td>
<td>5 : 9</td>
<td>Acento Minor 7th.</td>
<td>1018</td>
<td>20 - 0</td>
</tr>
<tr>
<td>8</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>450</td>
<td>80 : 81</td>
<td>Comma of Diatess.</td>
<td>22</td>
<td>8 : 15</td>
<td>Just Major 7th.</td>
<td>1088</td>
<td>19 - 8</td>
</tr>
<tr>
<td>9</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>455</td>
<td>243 : 256</td>
<td>Pyth, Limma.</td>
<td>90</td>
<td>128 : 243</td>
<td>Pyth, Major 7th.</td>
<td>1110</td>
<td>18 - 4</td>
</tr>
<tr>
<td>10</td>
<td>अर्धगुन्धां, करण्या.</td>
<td>आ.</td>
<td>480</td>
<td>Total carried from प to र</td>
<td>762</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total from प to र</td>
<td>498</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Grand Total</td>
<td>1200</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*European system tempers the fifth, while in Hindu Music Fifth or र is kept unaltered (सर्वत्र), as the backbone of the Scale.*

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Vibrations which is fifth above प, ह (261 vibrations) is minor third of क्रं त्र and it has its corresponding त्र. त्र. are generally accepted by almost all the systems of Indian Music. There are several systems in vogue, e.g. the Guburchi, as sung by Abdul Karoon, the front of the Kollapur Durbar, and several systems in the Karnatic. All these systems accept the Shrutes, though their several advocates differ as to the combination.
9. Now when we look at the intervals newly obtained in our Chromatic Scale of twelve notes (Table C), we find that another interval smaller than 15:16 which we get in the Diatonic Scale, puts in its appearance twice, and that is 24:25. It must not be overlooked, because it is an interval lying between two consecutive notes of the musical scale viz. कृति न. and कृति न., which form part of harmonies. Therefore this interval has been considered as an important and the most suitable interval to be put in for the purpose of evolving a still finer scale. The same process which has been described above for the Chromatic scale of twelve notes, has been followed in developing the scale of twenty-two notes or सुनित scale as defined in रामनिषेध. For purposes of easy reference, Table D of the twenty-two Shruti scale is given below, with the musical intervals, lengths of wire of the Diapason, Mr. Ellis' cents number of Shrutes or 'degrees' (as called by Mr. Ellis), and names of the note etc.

10. From this table it will be seen that when the smaller interval of 24:25 having 70 cents, is put in between र (240 vib.) and कृति न. (256 vib.), another note called कृति रि (250 vib.), bearing the simple ratio of 24:25 and having 70 cents makes its appearance. In the same way a third रि (266 vib.) appears between कृति न. and कृति न. Similarly two संवधि (consonant) notes are introduced in the second half of the scale viz. कृति रि, प. and म. भ. It is to be clearly noted here that these notes कृति रि, कृति रि, and रि, in the first half of the scale, and कृति रि, कृति रि, and म. भ. in the second half are called by संवधि author of रामनिषेध as रिकान संवधि, and are recognised by him. [Vide सुनित Table in Mr. Banhatti's विजय ग्रंथ, Pt. III, Page 16.] In the same way कृति रि, प. and म. भ. and the corresponding कृति रि, प. न. त. and म. भ. त. have been introduced newly. It is already stated that like कृति न. is also to be kept unaltered (अधिकार); and the two are to form the back-bone of the scale. The interval between म and भ which is the largest viz. 8:9, cannot therefore be neglected. Therefore the Aryan authors divided the same into four parts and assigned notes which are considered as बिजूतिन or modifications of म and not of भ [vide सुनित Table in Mr. Banhatti's book.] These notes are कृति न., कृति म., कृति न., and म. भ. त., having intervals of 24:25, 128:135, and 125:128 respectively, with 70, 92, 42 cents respectively, making up a total of 204 cents which are
assigned to the higher interval of 8:9 lying between \( n \) and \( g \). In this manner we have got \( l_1 + \frac{4}{1}l_2 + \frac{4}{1}l_3 + \frac{1}{1}l_4 + \frac{4}{1}l_5 \) (upper), making up a total of 23 notes including the octave. These results are given in the following Table D.

11. All the lengths given for the notes in these tables are those of the wire of the Diachord and they must not be confused with lengths of strings of playing instruments, such as Been, Satar etc. The difference between the instrument fixing a scale like a Diachord and a playing instrument consists in this, that in the playing instrument the height of the strings or wires above the frets necessarily varies from one to five millimetres, as has been shown by Mr. Ellis in his examination of several Śrīnāgas and the Śrīnāgas of Tanjore sent to him by Cap. Day. Unless we leave some margin for height the instrumental player cannot move the fingers from the different frets freely and with ease; and he cannot produce increased tension in order to have different shades, and \( s_m \) (mends) and \( s_r \) (ralis) are required for different modes (\( \text{राजस्व} \)) and modulates (\( \text{देशात्तक} \)). But it is to be observed that when the player puts pressure on the string when bringing it down to the fret, the increased pitch due to the pressure must per force increase the pitch. But in preparing an instrument of scale, which is in other words a Diachord, we must not leave any height whatsoever between the speaking string and the moving bridge. Now when we have prepared the above scale, we are to note down the different speaking lengths of the different notes, on the wire of the Diachord. When an instrument player wishes to set the frets to the instrument to a particular scale, he must keep this Diachord by his side and taking into account the tension caused by the pressure of his finger on the string, he must see whether the note on the playing instrument tallies exactly with that given by the Diachord. He must also while practising strike ear or voice to the different notes of the scale produced on the Diachord, and not the playing instrument; because the latter is likely to misguide him. So also while producing different notes or modified notes by mends (\( \text{राष्ट्र} \)) on the same fret on his playing instruments, he must not deflect the string indiscriminately, but should deflect it only to such an extent as will give him the exact note required, which will tally accurately with that given out in the Diachord. This can be attained only by long and patient study. Even gifted specialists like the late Bande Ali and his disciples Chenna Murad, Bhatkhat Ulla, Baidur Bux, Antumba Sadhale and Vrishnupant Joshi (Pakhwajis) required years of constant practice to train their ears and fingers to get the exact notes in their case. The Diachord is the exact standard of measurement for accurately determining the musical scale; in other words it affords us a means to measure musical notes, just as we have the rain gauge, the thermometer, the barometer etc. But the playing instrument, unless it is played upon by a specialist, is not the standard by which the musical scale can be accurately gauged, for the skill of the player must be taken into account. The Sanskrit authors clearly intended this, as they distinctly state the exact divisions of the length of the wire, for producing the different notes \( 1:2:3:4:5:6:7:8:9 \) \( s_m \), \( s_r \), \( d \), \( g \), and \( n \). They do not obviously intend that there should be any height whatever between the speaking string and the playing fret. Had this been the case, then the laws laid down by them (given above) would have given incorrect results. They intended the construction of the musical scale.

12. After having thus obtained these scales, let us now consider the Śruti problem. Among notable recent writers who have attempted to solve the question, may be mentioned Mr. Bhavanimo Pinglee, Mr. Balawant Tribalk Sahasrabuddhe, and Raja Surendra Mohun Tagore. I will consider the methods of Messrs. Pinglee and Sahasrabuddhe, first; and then examine the Raja’s method. They have taken it for granted that like vibration in a Śruti was the “unit” of measurement of the long interval (śruti) between a fundamental note and its octave and that 22 Śrutis is the number of periods of equal value. This is not the case. A Śruti is a sub-division of a note, may be a quarter or a third of a \( \text{n} \) \( s_m \) \&c., according to the position it occupies in the interval between any two consecutive notes.

13. For the purpose of comparing the Śruti Scale with the exact Scale (\( \text{दक्षिण} \)), they divided the entire length of the executive part of the wire into 44 units. I quote Mr. Sahasrabuddhe: “If a
monochord” says Mr. Sahasrabuddhe “be taken and a space equal to 44 units be measured and the bridge shifted to this point, the string when struck will yield a note; if we start with this note as the tonic or keynote and run through the gadhat by shifting the bridge (the Sanskrit writers affirm) the following facts will be observed. Shri will be produced at the distance of 44, Ri at 40, Ga at 37, Ma at 33, Pa at 31, Dha at 27, Ni at 24 and So again at 22, but the latter Shri will be twice as intense as the former."

Mr. Sahasrabuddhe has based the above theory on the wrong interpretation and application of Aryan 16 & 17 and the latter part of Aryan 21 of the śāśrīyaṃ śārīyaṃ quoted above.

Exact Hindu Scale—C D E F G A B C

Mr. Sahasrabuddhe’s—Sā Ri Ga Ma Pa Dha Ni Sā

And now when actual comparison is made by finding the ratios of the fundamental note with each of the successive 7 notes of the Shri scale thus wrongly demonstrated, we find none of the notes (except the octave) bear those simple ratios which a Hindu Scale as well as the European exact scale bear. This is quite plain from the following comparative table.

Shri scale as explained by Mr. Sahasrabuddhe.

The Hindu Exact

<table>
<thead>
<tr>
<th>Note</th>
<th>Hindu Scale</th>
<th>Exact Hindu Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shri</td>
<td>5\ hemisphere</td>
<td>C = 24 = 1</td>
</tr>
<tr>
<td>Ri</td>
<td>6\ hemisphere</td>
<td>D = 2</td>
</tr>
<tr>
<td>Ga</td>
<td>7\ hemisphere</td>
<td>E = 3</td>
</tr>
<tr>
<td>Ma</td>
<td>8\ hemisphere</td>
<td>F = 3</td>
</tr>
<tr>
<td>Pa</td>
<td>9\ hemisphere</td>
<td>G = 3</td>
</tr>
<tr>
<td>Dha</td>
<td>10\ hemisphere</td>
<td>A = 5\ hemisphere</td>
</tr>
<tr>
<td>Ni</td>
<td>11\ hemisphere</td>
<td>B = 5\ hemisphere</td>
</tr>
<tr>
<td>So</td>
<td>12\ hemisphere</td>
<td>C' = 8\ hemisphere</td>
</tr>
</tbody>
</table>

It will be found that each one of the intermediate notes of the Shri scale as explained above bears a complicated and rather higher ratio with the fundamental note and that none of the lengths shown on the left side gives out notes which are obtained in the śāśrīyaṃ śārīyaṃ (Table A) and which we actually sing and play. But the fact is otherwise. Our artisters actually sing and play notes which bear simple ratios with the fundamental note.

14. Mr. Chinna Swami Mudaliar A. of Southern India, wrote a large volume entitled “Oriental Music,” but has left untouched the question of ādī notes or Shri notes as being a very complicated and intricate one. How the labours of Messrs. Pingale and Sahasrabuddhe, were not productive of successful solution, I have already shown above. Raja Suranduna Mohan Tagore also attempted to determine the position of the twenty-two Shri notes. He divided the whole length of the wire into two halves, the whole length giving the ādī or fundamental note and the half giving the ādī, the octave; both these notes are correct. Again he divided the first half into four equal parts, each being one-fourth of the whole length. The first quarter (of the wire) he subdivided into nine equal parts calling each part a Shri note. At the end of the ninth part is sounded a note π (at 1 \ of the wire) which is correct. In the next quarter
of the wire he made thirteen equal subdivisions, each being also called a Shrutee. Thus in all he got the twenty-two Shrutees. Let us now see whether according to the Raja's apportionment we get the other notes correctly. Now there are three Shrutees for the $\frac{4}{5}$ part of the Diatonic Major Scale. (Vide, राजसूय क्रम के पाया). According to Raja Surendra Mohan Tagore's division, these Shrutees would mean three parts out of the nine equal parts in the first quarter of the whole speaking length of the wire; the length of these three parts would come to $\frac{1}{3}$ part of the whole wire ($\frac{1}{3}$ wire divided into 3 parts, each part $= \frac{1}{3} \times 3 = 1$ part of the whole length). Thus the $\frac{4}{5}$ Shrutee will be produced, on the $\frac{1}{3}$ part of the whole wire, according to Raja Surendra Mohan Tagore's method; i.e. $\frac{4}{5}$ Shrutee will be produced on a length of 33 ($= \frac{33}{5} \times 33 = 33$ inches). But as we have seen, the musical interval between $\frac{3}{5}$ and Shrutee is $8:9$; the pitch of $\frac{4}{5}$ Shrutee is $\frac{4}{5}$ of $\frac{3}{5}$; so if we invert this ratio of pitch, we get the length required. ($= 33 \times \frac{5}{3} = 32$ inches). Thus we get 32 inches as the length for $\frac{4}{5}$ Shrutee. Consequently, Raja Surendra Mohan Tagore's Shrutee is flatter or कीमत than the just Major Second which we actually sing and play; the interval also is smaller than the correct one. Similarly incorrect results might be obtained for the other notes, by following Raja Surendra Mohan Tagore's method.

15. I now proceed to show how Cap. Day and Mr. A. J. Ellis, in their attempts to find out the positions of the twenty-two Shrutees, were not successful, perhaps misled, partly by the erroneous information of recent publications and partly by the assumption that the Hindu writers have followed or are inclined to follow the equal 'temperament' system of Europe in developing their Chromatic Scales. The lines on which Mr. Ellis tried to solve the question of the Shrutees may be seen in the following extract from his paper read before the Royal Society of Arts in 1885. Cap. Day also was similarly misled, and he follows Mr. Ellis' division. Mr. Ellis follows the lines suggested by Raja Surendra Mohan Tagore, whose methods I have already referred to. In his paper Mr. Ellis says:

"Now we do not know precisely what a degree is. And hence any representation of these differences with exactness is impossible. But we may obtain a tolerably approximate notion thus: suppose the fixed notes to have been those already described in the old C Scale, so that C to D, F to G, and G to A, have each 204 cents, and a degree of such an interval should be a quarter of that amount, or 51 cents. The interval D to E, or A to B, has only 162 cents, and but only 3 degrees, so that each degree has 54 cents. Finally, the interval E to F, or B to C, has 112 cents, and only 2 degrees, hence one of these degrees has 56 cents. The modern Bengali division gets over the difficulty thus: The C string is divided in half, giving the Octave; the half nearest the nut is again halved giving the fourth, F. The part between the nut and F is divided into 9 equal parts, each giving a degree; and the other part from F to the Octave, is divided into 13 equal parts, each giving a degree. From these indications it is possible to calculate the values of each degree and assign the notes. In the following table I give the number of degrees and the calculation of their value on both plans, old and new, with the names of the 19 Indian notes assuming that pitch varies inversely as the length of the string as shown by the position of F and the Octave and that any errors thus arising have been corrected by our:

<table>
<thead>
<tr>
<th>Degrees</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notes</td>
<td>C</td>
<td>Dfl</td>
<td>Dfl</td>
<td>−</td>
<td>Dfl</td>
<td>Efl</td>
<td>Efl</td>
<td>E</td>
</tr>
<tr>
<td>Old</td>
<td>0</td>
<td>51</td>
<td>102</td>
<td>153</td>
<td>204</td>
<td>254</td>
<td>305</td>
<td>356</td>
</tr>
<tr>
<td>New</td>
<td>0</td>
<td>49</td>
<td>90</td>
<td>140</td>
<td>194</td>
<td>244</td>
<td>294</td>
<td>344</td>
</tr>
<tr>
<td>Degrees</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
</tr>
<tr>
<td>Notes</td>
<td>Esh</td>
<td>F</td>
<td>−</td>
<td>Fsh</td>
<td>Fsh</td>
<td>G</td>
<td>Afl</td>
<td>Afl</td>
</tr>
<tr>
<td>Old</td>
<td>442</td>
<td>498</td>
<td>543</td>
<td>589</td>
<td>637</td>
<td>685</td>
<td>733</td>
<td>781</td>
</tr>
<tr>
<td>New</td>
<td>445</td>
<td>498</td>
<td>543</td>
<td>589</td>
<td>637</td>
<td>685</td>
<td>733</td>
<td>781</td>
</tr>
</tbody>
</table>

The only values agreeing in each are C, D, F, while new Ffl is the just Minor Third, a mere accident. The 9 degrees from C to F vary from 40 to 63 cents and then there is a sudden break, after which the 13 degrees from F to the Octave vary from 45 to 65 cents. This is the first intelligible presentation of the Indian scale which I have been able to effect. It will be seen that C, Dfl, D, Efl, E, F, Fsh, G, Afl, A, Bfl, B are represented pretty well by our equally tempered notes, but that the 7 intermediate notes Dfl, Efl, Fsh, could only be
tempered on the Quarter-tone system used in Syria. Hence, in the usual transcription, these notes are identified with some of the others, possibly D♯ with D (not with C), E♭ with B (not with D), E♭ with F (as usual), F♯ with E (not with G), A♭ with A (not with G), B♭ with B (not with A), and E♭ with C (as usual). These comparisons necessarily injure the original character of the music, and give it a harmonisable appearance which is entirely foreign to Indian music."

16. But our method of dividing a whole tone either of 204 or 182 or 112 cents into four, three or two tones as the case may be, is not to make equal divisions, as has been supposed and done by Mr. Ellis; but the divisions are to be made in accordance with the intervals lying between two consecutive notes. For instance the interval between and , the first and second note of our Major Diatonic Scale is 8:9 with 204 cents. Now suppose we want to divide this greater interval into two smaller ones or tones. Then we introduce between and , a third note called , or D flat, which bears to the fundamental note the ratio of 15:16, because this same ratio or musical interval already lies between the third and fourth note and , or between the seventh and eighth note, and , of our Major Diatonic Scale. This done, the three notes , and , will have the following two musical intervals lying between them. If has 340 vibrations as a second of time, has 270 vibrations, the interval being 8:9. When , with 250 vibrations is introduced between the two notes, then the three notes (240 vib.), (256) and (270 vib.) stand to one another in the ratio of 15:16, and 128:135; having 112 and 92 cents respectively, in all making up 204 cents. But this has not been done by Mr. Ellis. He has divided the whole tone of 204 cents into four equal parts and has assigned 51 cents to each part. This is evidently incorrect and these notes obtained by equal divisions are not actually sung in practice. Similarly are obtained wrong results for other notes also.

17. Again in assigning each subdivision to a Shruti or "degree" of the twenty-two cycle, a wrong start is generally made by some writers; because the first Shruti or degree (though it begins from the 0) on which is marked) is to be marked where the first Shruti ends and not where it begins. According to the rule given in of tuning strings and placing the twenty-two roots, each indicating a Shruti, the first root or Shruti or "degree" is to be placed after the zero (0) or the fixed bridge which is the whole length of the wire or the vibrating length rests, and when sounded gives the fundamental note. Accordingly the correct and proper way of assigning or marking shritis is that noted in the Table D; and is different from that adopted by Mr. Ellis. By this process, the figure (0) comes on or C, the first Shruti on the second note, and the twenty-second Shruti exactly comes on the octave or , giving 1200 cents. And according to Mr. Ellis, the twenty-second Shruti comes on or or or B sharp, having 1135 cents only.

18. Similarly Mr. Ellis made another experiment. He heard Raja Ram Pal Singh playing on his (Satar)—a playing instrument, at four different settings. With the aid of a tuning fork, and assisted by Mr. Hipkins, a noted musician, he observed and took down cents for each note of the Diatonic Scale at each setting and got the following results.

Scales set by Raja Ram Pal Singh.

<table>
<thead>
<tr>
<th>First and Fourth setting:—</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. 1st.</td>
<td>0</td>
<td>183</td>
<td>271</td>
<td>534</td>
<td>686</td>
<td>872</td>
<td>988</td>
</tr>
<tr>
<td>4th</td>
<td></td>
<td>174</td>
<td>230</td>
<td>477</td>
<td>697</td>
<td>908</td>
<td>1114</td>
</tr>
<tr>
<td>New</td>
<td>204</td>
<td>374</td>
<td>494</td>
<td>686</td>
<td>896</td>
<td>1070</td>
<td>1290</td>
</tr>
<tr>
<td>Notes</td>
<td>C</td>
<td>D</td>
<td>E♭</td>
<td>F</td>
<td>G</td>
<td>A</td>
<td>B♭</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second setting:—</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. 1st.</td>
<td>0</td>
<td>183</td>
<td>271</td>
<td>534</td>
<td>686</td>
<td>872</td>
<td>988</td>
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<td>4th</td>
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<td>174</td>
<td>230</td>
<td>477</td>
<td>697</td>
<td>908</td>
<td>1114</td>
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<tr>
<td>New</td>
<td>204</td>
<td>374</td>
<td>494</td>
<td>686</td>
<td>896</td>
<td>1070</td>
<td>1290</td>
</tr>
<tr>
<td>Notes</td>
<td>C</td>
<td>D♭</td>
<td>E♭</td>
<td>F</td>
<td>G</td>
<td>A♭</td>
<td>B♭</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third setting:—</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. 1st.</td>
<td>0</td>
<td>111</td>
<td>314</td>
<td>534</td>
<td>686</td>
<td>828</td>
<td>988</td>
</tr>
<tr>
<td>4th</td>
<td></td>
<td>99</td>
<td>316</td>
<td>498</td>
<td>686</td>
<td>787</td>
<td>1011</td>
</tr>
<tr>
<td>New</td>
<td>0</td>
<td>374</td>
<td>498</td>
<td>686</td>
<td>896</td>
<td>1070</td>
<td>1290</td>
</tr>
<tr>
<td>Notes</td>
<td>C</td>
<td>D♭</td>
<td>E♭</td>
<td>F</td>
<td>G</td>
<td>A♭</td>
<td>B♭</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fifth setting:—</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. 1st.</td>
<td>0</td>
<td>90</td>
<td>366</td>
<td>490</td>
<td>707</td>
<td>781</td>
<td>1080</td>
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<tr>
<td>4th</td>
<td></td>
<td>90</td>
<td>374</td>
<td>498</td>
<td>686</td>
<td>877</td>
<td>1070</td>
</tr>
<tr>
<td>New</td>
<td>0</td>
<td>374</td>
<td>498</td>
<td>686</td>
<td>877</td>
<td>1070</td>
<td>1290</td>
</tr>
<tr>
<td>Notes</td>
<td>C</td>
<td>D♭</td>
<td>E♭</td>
<td>F</td>
<td>G</td>
<td>A♭</td>
<td>B♭</td>
</tr>
</tbody>
</table>

These results when compared with the cents, put in my Diatonic Major table will show that the cents obtained by Mr. Ellis have not
been correct ones. The observations noted in the first line of the first setting do not tally with those of the second setting, nor those of the third setting with those of the fourth setting. Even the cents observed for the Octave (e) differ for all the four settings. But there is no wonder that such varying results were obtained. Because Mr. Ellis himself says that the setting of the frets was a "pure matter of ear and memory"; and "the frets were moved somewhat hastily and perhaps were not arranged with the accuracy that would have been attained by a professional musician."

19. I may state in brief that attempts were made in three directions or ways to solve the question of Shrutes. Messrs. Pingale and Sahasrabuddhe among others tried to solve the question by dividing the whole speaking length of the wire into forty-four (44) equal units, and then trying to assign the positions of the twenty-two Shrutes. The faults of their method have been explained above. Raja Surendra Mohun Tagore divided the string into two equal parts, which again were subdivided into equal parts, each containing a varying number of equal units which he designated as the Shrutes. I have already shown the erroneousness of this method. Mr. A. J. Ellis divided each interval into as many equal parts as there were Shrutes: 1, 2, 3, or 4. I have shown above how this method also does not give a satisfactory solution. The reason as to why Mr. Ellis could not get satisfactory results in all his experiments were: first, as he admits, the original treatises on Hindu Music were not accessible to him. Secondly, the experiments were made on fretted instruments. In these instruments, the pressing of the wire or string down to the fret increases the tension, thereby increasing the pitch. The height of strings above the frets in different instruments varies largely, say from 4 to 6 millimetres. Again in playing the same notes on different occasions, the same performer is likely to commit mistakes on account of defect of ear or want of proficiency. And, as is admitted by Mr. Ellis himself, "it is exceedingly difficult to determine the minute differences of pitch between notes with qualities of tones so different as those of plucked strings and tuning forks."

20. Now it may be asked that the 22 Chromatic notes or the Shrutee Scale (Table D) do not apparently correspond to those assigned for each of the 7 notes in the Diatonic Major Scale. This point is cleared thus. As explained by Sanskrit writers a Shrutee is any audible musical note given by plucking the wire against the bridge; or to speak in terms of the scientist of the West, Shrutee is the smallest musical interval, lying between any two consecutive notes of the musical scale. I may make myself clear by giving an example. The musical interval between र and લ of the Diatonic Major Scale (of eight notes including the octave) is 8:9. This interval was first divided into three smaller ones, each being called a Shrutee. The author of राजधानी first laid down that that ल has three Shrutes, But for developing this Diatonic scale into the Chromatic scale of twelve or twenty-two notes, it was also laid down that and are to be kept unchanged. Therefore the eight Shrutes of and (four each) had to be distributed among the other notes, after retaining one for each (one for and one for ). Thus to distribute the remaining six Shrutes among the other notes, it was necessary to divide the interval 8:9 between and . into four विहृत वर्ण, each called a Shrutee. Under these circumstances it will be easily seen that a Shrutee is not a unit of measurement, as has been supposed to be the case by several writers; but it is an interval lying between any two consecutive notes, and as such is liable to be subdivided into as many smaller intervals as there may be विहृत वर्ण, or modifications of tones. Shrutes may be more than twenty-two also, this number being the one generally accepted, some Sanskrit authors recognising 32, some 66 and some saying that they are innumerable.

21. It will thus be seen that in forming the Chromatic Scale of twenty-two Shrutes, the same method of introducing smaller ratios or intervals is observed, as that pursued in forming the scale of twelve notes. The rule of perfect concord on which Sanskrit writers put so much emphasis, has been strictly observed in all the scales. It will also be clear how the Chromatic scale of twelve notes has been formed out of the Diatonic scale of seven notes, and how the scale of 22 notes or the Shrutee scale has been worked out from that of twelve notes. I have already explained the methods which the Sanskrit writers have adopted for evolving higher and finer scales. It is to be noted that these scales which are worked
out strictly on the lines laid down by our Sanskrit authors are constmcted on a thoroughly scientific basis; and they fully (through their intervals) satisfy the test of the system of cents adopted by Mr. A. J. Ellis. The theory of the स्वरसंक्षेप or Diatonic Major scale has already been propounded above. From all this it will be evident that the Sanskrit writers were fully cognizant of the laws of the constitution of musical sound, which have been approved of by modern science; that they worked out their scales not "arbitrarily" but on definite and regular fixed laws; and that in formulating their scales they were led not by "artificial" ideas, and were guided not by "capricious" suppositions, but proceeded on precise rules and principles.

22. By means of the Diachord and these tables which have been worked out from Sanskrit writers, the Musical Scale can be determined with mathematical precision. The Diachord with its moving bridge gives us an accurate means of determining the several notes correctly; and the notes of the instrumentalist or vocalist can be tested by referring them to those produced on the Diachord. Like the tuning forks of the West which are used for testing the correctness of the notes, the Diachord with its moving bridge serves the same purpose. The ear, which at present chiefly guides the musician—instrumentalist or vocalist—is not always an infallible test of the correctness and justness of the notes; it is liable to vary in its capacity of judgment. Hence the great importance of the Diachord.

23. The experiments which I made with the Diachord, were conducted with the assistance of Prof. Abdul Kareem, an expert professional vocalist of renown. The results of the experiments which I have been making for the last few years, have been verified by him. And it is no small satisfaction to me, and I believe, as well as to the public, that the results of my study of the theory of the Hindu Musical Scale as propounded by the old Sanskrit writers have been approved of and amply corroborated by eminent professional artists like Prof. Abdul Kareem. It might be stated here that but for the kind help and open-hearted assistance of the Professor, I should not have been able to lay these few ideas before the public. I cannot but here express my heartfelt obligations to the works of modern Indian writers like Messrs. Kunte, Pingale, Sahasrabuddhe, Banbhatti, Chinnu Swami Mallar, and Raja Surendra Mohun Tagore among others; and also to the works of European writers like Sir William Jones, Capt. Day, Messrs. Bosanquet and A. J. Ellis, for the valuable light of information and criticism which they throw upon the subject. To the study of Hindu Music which these writers made and to their labours for regenerating and encouraging this Art of Arts, I humbly and respectfully add my share, infinitesimally small though it is. As endeavours in this direction are carried and pursued further, it is quite possible that more light will be thrown on the subject; and perhaps the results which I have obtained at present might undergo modification. I stand open to correction.

24. I cannot conclude without making an appeal to the public in the interests of this Art of Music. At present, broadly speaking, the Art is confined to two classes, professional Musicians—Vocalists or Instrumentalists—and the operatic (दास्ता) stage. And if the excellence of the Art is to be found anywhere, it must be admitted to exist among the Professional Musicians only. All credit is due to them, because in spite of the absence of material encouragement in recent times, they alone have still preserved and protected this ancient and richly developed Art from total extinction. Our Hindu religion, which is so comprehensive in its relation to life as to hardly leave any subject outside the sphere of its influence, has done not a little, in fact it has done the utmost, by means of the numerous rites and ceremonials which embody music as a part of their programme, to preserve, cultivate and develop this Art. The great stimulus which Institutions like the Gayan Samaj of Poona and other centres, and the Gandharva Maha Vidyalaya of Lahore (the Academy of Indian Music, conducted by Pandit Vishnu Digambar Palaskar), have given to the study of this Art by creating a wide interest among the people, must be candidly acknowledged. All these attempts are surely commendable, but looking to the steady and slow decline of this Art in recent times, it must be recognised that they are insufficient for the purpose in view. The blind imitation of the Westerns which was the besetting sin of our educated people about 50 years ago, has had its evil effects on Music also as on other spheres of activity. No other
Institution succumbed to the passion so completely as our Dramatic Stage. The harmonium and piano of the West soon took the place of the Veena, Bin and the Sarangi and the musical precision and rich melody of old soon gave place to imperfect and graceless music. Instruments of the harmonium family with fixed keys which reign supreme at present on our stage, are based on the European Temperate Scale, which is admitted by European musicians themselves to be a defective scale. As observed by Professor Blasserme, "it is an incorrect scale. It has destroyed many deficiencies and has given to music, founded on simple and exact laws, a character of almost coarse approximation." These are instruments with fixed keys, they restrict a musician by compelling him to choose a note out of a fixed scale, and that too arranged on an approximation to natural tones. Again the notes on the piano or harmonium die away rapidly and do not give rise to overtones which are the essentials of rich and good music. Aroha (ascent), Avaroha (descent), Murchchhaya (a quarter-tone), Mand, or Ghasia—all these are necessary for the proper execution of a Raga or Ragini; and in the very nature of things, they cannot be had on the harmonium or piano. Yet our musical pieces which are composed in accordance with the rules of Indian Music, are sung on the stage in accompaniment with these instruments! For example, the singer of ग्रहण वालि (a Raga), obtains on the harmonium not the counterpart of his Raga, but quite a different tune; and the result is the creation of imperfect music and ludicrous incongruity. And yet, it is this incongruity which is enacted and tolerated on our dramatic stage, night after night! As Professor Blasserme rightly observes, "music founded on the temperate scale must be considered as imperfect music and far below our musical sensibility and aspirations. That it is endured and even thought beautiful only shows that our ears have been systematically falsified from infancy."* How truly do these remarks hold good in our case, may

*Hon. Mr. Muir Mackenzie explained to me that vocal music and music on instruments of the violin family is sung and played in the exact scale by connoisseurs only in Europe. But I would add that the temperate scale has been adopted in Europe to suit the exigencies of instruments with fixed keys. Its advantages for the European system which is dependent on transposition and unlimited modulation from one key to another are felt to far outweigh its disadvantages, and there is very little probability of a return being made to the natural scale in the near future in Europe. At the same time Indian Music which is not dependent on extensive modulation has no need whatever for a tempered scale.