Conclusion

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In the foregoing Chapters we have witnessed briefly the mathematical and physical basis of the notes employed in Indian classical *(North Indian style)* and their combination into Grams, Thatas and Ragas. We have also been able to derive, from a purely mathematical viewpoint, the conditions necessary for certain combination of musical notes to have a pleasant and musical effect on the ears. On this basis it is possible to evaluate the musical richness of a particular scale *(be it a Gram or a Thata).*

To start with, we saw that the musical pleasantness of a single note depends mainly upon the quality of its wave form provided loudness and pitch *(frequency of the vibrations involved)* is without any harmonies does not appear musical to the ears. Harmonies or subsidiary frequencies are essential ingredients of a musical note.

When a single note *(say A)* has been established, those notes appear musically related to this note which have a predominant frequency equal to its *(A's)* second, third, fourth, fifth and sixth harmonies. if the note *"A"* is taken to be Shadaj *(Sa)* the second and fourth harmonics give rise to Shadaj of the Tar Saptak *(Sa)*, the third and sixth harmonics generates Pancham *(Pa)* and the fifth harmonic defines Gandhar. since the second and fourth harmonics define the same note in a higher octave, we are left with two basic musical relationships - Shadaj Pancham Bhav or the third harmonic relationship *(frequency ratio = 5/4)*. From Shadaj Pancham Bhav another relationship known as Shadaj-Madhyam Bhav *(frequency ratio 4/3)* can be derived by raising the lower note by an octave or by lowering the higher note by an octave. similarly by raising the lower note by a frequency ratio 3/2 or by lowering the higher note by the same ratio, the Shadaj-Shuddha Gandhar Bhav is converted into Shadaj Komal Gandhar Bhav *(6/5)*. Thus we have four types of musical relationships.

Sa - Pa *(Frequency ratio = 3/2)*
Sa - Ma *(Frequency ratio = 4/3)*
Sa - Ga *(Frequency ratio = 5/4)*
Sa - Ga' *(Frequency ratio = 6/5)*

Ideally, in a musical scale containing seven notes :

Notes separated by the notes *(Sa-Pa-Re-Dha etc.)* are expected to exhibit Sa-Pa type relationship, Notes separated by two notes *(Sa-ma, Re-Pa etc.)* are expected to exhibit Sa-Ma type relationship *while* alternate notes (Sa-Ga, Re-Ma)
are expected to exhibit one of the Shadaj Gandhar type relationships.

However we have seen that theoretically it is impossible for any musical scale to exhibit these relationships in all possible pairs. At least one pair would fail to exhibit the relationship it is expected to.

We have also seen that the ideal method of construction of a musical scale could be to follow the successive third harmonic or fifth harmonic method. However, it is mathematically impossible for either of these sequences to close a any state *(to come back to Shadaj)* although the successive third harmonic or fifth harmonic method gives 12 notes before coming to a note *(13th.)* fairly close to Shadaj. Since a perfect musical scale is impossible in this sense, there has been a multiplicity of scales which have their own advantages and disadvantages.

We have discussed the Grams *(seven-note scales)* defined by Bharat which were constructed on very sound scientific basis. Although a full description of the Gandhar Gram is not available the author has made a conjecture of its notes and Shrutis and how rich it is in terms of Shadaj Gandhar relationships.

We have also been able to define the musical richness of a scale in terms of the pairs or notes which exhibit the relationships they are expected to. for instance, in a seven note scale, 7 pairs are expected to exhibit Sa-Pa type *(or Sa-Ma type)* relationships and another 7 are supposed to be related by either Sa-Ga or Sa-Ga' type relationships. If we prescribe that out of these 14 pairs, at least 9 must be musically related and also that pairs by any one type of relationships should not be less than 4, we can derive 22 Grams as against 3 *(including Gandhar Gram)* mentioned in the ancient literature. In fact, we admit certain unusual frequencies between successive notes, we get 17 more Grams.

Similarly we have seen that although Shrutis are infinite, it is possible to derive 87 *"first order Shrutis"* on theoretical considerations as against 22 traditional Shrutis. Many of these 87 Shrutis *(which are not included in the 22 traditional ones)* are in use knowingly or unknowingly.

Coming to Thatas, which are seven-note scale in which the notes are in a particular order, *(in a Gram, only cyclic order of the notes is important)* we have discussed how many Thatas are mathematically possible and how many of them are musically rich one the basis of the yardstick developed above. e have also discussed the musical richness of the prevalent Thatas along with their possible variations. Sometimes, as we have seen, by varying a note slightly *(by a Shruti)* we move into a different Gram although the Thata appears to be unchanged. As compared to a Gram, a Thata is a more crude system of defining a musical scale.

We have also seen how the ancient Gram gave rise to Murchhana, Taanas and Jatis *(prototypes of Ragas)* which were bound by certain rules to preserve their essential features. Modern Ragas are constructed by Thatas and their defining rules are similar to that of Jatis.

We have also seen how various Shrutis are employed in different Ragas or even in the same Raga at different times in order to highlight particular musical relationships or combinations do exist certain Ragas which cannot be explained in terms of the musical relationships defined above.

It would be very immature to claim that music can be completely explained on the basis of the principles of physics and mathematics. There are several other dimensions of music which cannot be captured by the physical sciences. In fact, if we want to enjoy music, we must forget all preconceived notions including the theory developed in this book. Even for learning music, this theory would be of little practical help. This is purely an academic exercise for the inquisitive. It may please a mathematician who loves music and it may pleasantly surprise a musician who may be inclined to dabble in physical sciences.

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