

The Sounds of Music: Science of Musical Scales*

III: Indian Classical Music

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In the previous articles of this series, we have discussed the development of musical scales particularly that of the heptatonic scale which forms the basis of Western classical music today. In this last article, we take a look at the basic structure of scales used in Indian classical music and how different *ragas* are generated through the simple process of scale shifting.

Introduction

In a certain generation many people, all around the world, received their first lesson in Western musical scales from Julie Andrews when she and the von Trapp children sang ‘do-re-mi...’ in *The Sound of Music*. In India, what surprised the uninitiated is the equivalence of this scale with the ‘*saptak*’ (a scale containing seven basic notes) that forms the basis of Indian traditional music.

Indian classical music is a genre that is prevalent in the Indian sub-continent and parts of the far-eastern reaches of South Asia. There exist two major traditions – the North Indian tradition called the *Hindustani* classical, and the South Indian variant known as the *Carnatic* classical. They began as one but later diverged into two separate forms because of various historical reasons. However, much of the basic structure remains the same till date.

The guiding principle of Indian classical music is to exploit the freedom accorded by the special nature of human sensitivity¹ to the acoustic frequencies. The primary characteristic of this genre



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Keywords

Swara, saptak, murchhana, raga.

A *Raga* is built from a basic scale called a *thaat*.

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Table 1. Correspondence between the Indian *shrutis* and the Western notes. Note that the *shuddha swaras* coincide with the pure notes of C-major. This is because the Indian base note *s* has been matched to the Western *C* and Indian *saptak* is intrinsically a major scale. The absolute frequencies has been obtained by setting *A* to 440 Hz.

<i>Shruti</i>	ratio	ν (Hz)	Note	ν (Hz)
<i>Chandovati (sa)</i>	1	261.6256	C	261.6256
<i>Dayavati</i>	256/243	275.6220	C#	277.1826
<i>Ranjani</i>	16/15	279.0673		
<i>Ratika</i>	10/9	290.6951		
<i>Raudri (re)</i>	9/8	294.3288	D	293.6648
<i>Krodha</i>	32/27	310.0747	D#	311.1270
<i>Vajrika</i>	6/5	313.9507		
<i>Prasarini (ga)</i>	5/4	327.0319	E	329.6275
<i>Marjani (ma)</i>	4/3	348.8341	F	349.2282
<i>Rakta</i>	45/32	367.9109	F#	369.9944
<i>Sandipani</i>	729/512	372.5098		
<i>Alapini (pa)</i>	3/2	392.4383	G	391.9954
<i>Madantī</i>	128/81	413.4330	G#	415.3047
<i>Rohini</i>	8/5	418.6009		
<i>Ramya (dha)</i>	5/3	436.0426	A	440.0000
<i>Ugra</i>	27/16	441.4931		
<i>Ksobhini</i>	16/9	465.1121	A#	466.1638
<i>Tivra</i>	9/5	470.9260		
<i>Kumudvati (ni)</i>	15/8	490.5479	B	493.8833
<i>Manda</i>	243/128	496.6798		
<i>Chandovati (sa')</i>	2	523.2511	C	523.2511

is that it is based on a standard set of melodic forms (*ragas*), which are themselves built from a basic set of scales (*thaat*). The *ragas* basically define the overall mood of the music by specifying scales (ascending and descending, which may or may not be the same) and provide the general prescription according to which a piece of music should be composed or performed. As there is no rigidity about a set piece of music, a musician is entirely free to bring her/his individual flavour to the composition as long as the prescription specific to a particular *raga* is adhered to.

¹The Sounds of Music: Science of Musical Scales: I. Human Perception of Sound, *Resonance*, Vol.24, No.8, pp.891–900, 2019.



1. Basic Structure

In Indian music there are 7 pure notes (*shuddha swara*) – *sa* (*shada*), *re* (*rishabh*), *ga* (*gandhar*), *ma* (*madhyam*), *pa* (*pancham*), *dha* (*dhaiwat*) and *ni* (*nishad*). The first and the fifth notes – *sa* and *pa* – have fixed frequencies and are commonly known as *atal swaras* (invariant notes). The other 5 notes are variables, and the variants are known as the *vikrita swaras* or the impure notes. These impure notes are $\mathcal{R}, \mathcal{G}, \mathcal{D}, \mathcal{N}, \mathcal{M}$ corresponding to the *komal* (flat or lower frequency) variants of *re, ga, dha, ni* and *teevra* (sharp or higher frequency) variant of *ma* respectively. An octave consists of the seven pure notes and is known as a *saptak*, the eighth note having twice the frequency of the first note. In reality though, a *saptak* contains 12 notes – 7 pure and 5 impure. The seven pure notes are obtained according to the ratio – 1, 9/8, 5/4, 4/3, 3/2, 5/3, 15/8 between the consecutive notes. From our earlier discussion² it is easy to see that this corresponds very closely to the **Major** scale of the Western tradition, as can be seen from *Table* [1], though the temperament used is neither Pythagorean nor the ETS, but the *Just*.

In traditional Indian music, a total of 22 microtones or *shrutis* were in use instead of the 12 tones discussed above. The practice continues to be the same in the South-Indian (Carnatic) music though the North-Indian (Hindustani) system is now more or less 12-tone based. The division of the *saptak* in 22 *shrutis* exploits the fact that there exists a minimum interval (in pitch or frequency) that can be distinguished by the human ear. (Theoretically, an infinite number of *shrutis* are possible, but any practical division would depend on the actual size of the frequency interval that a listener can discern or a musician can produce.) The list of *shrutis* has been shown in *Table* 1, along with the pure notes and their correspondence with the Western scale. It can also be seen from *Table* 1 that the difference between the frequencies of notes in the Indian system and the Equal-Tempered-Scale (ETS) are rather small. In fact, with the introduction of the reed instruments (piano, harmonium, etc.) in the Indian music scene (in

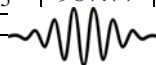
²The Sounds of Music: Science of Musical Scales: II. Western Classical Music, *Resonance*, Vol.24, No.9, pp.1015–1023, 2019.

The Indian *saptak* roughly corresponds to the **Major** scale of Western tradition, and consists of 12 *swara* – 7 *shuddha* and 5 *vikrita*.



Table 2. Indian *saptak* - *mandra-saptak* notes are denoted with *hasanta* symbols (,) and *tar-saptak* notes are denoted with *ref* (') symbols. (There exist other styles of notation to distinguish the notes in different *saptaks*.)

Key	Note	ν (Hz)	<i>Saptak</i>	
W	C ₃	130.81	sa,	Mandra
B		138.59	R,	
W	D ₃	146.83	re,	
B		155.56	G,	
W	E ₃	164.81	ga,	
W	F ₃	174.61	ma,	
B		185.00	M,	
W	G ₃	196.00	pa,	
B		207.65	D,	
W	A ₃	220.00	dha,	
B		233.08	N,	
W	B ₃	246.94	ni,	
W	C ₄	261.63	sa	
B		277.18	R	
W	D ₄	293.67	re	
B		311.13	G	
W	E ₄	329.63	ga	
W	F ₄	349.23	ma	
B		369.99	M	
W	G ₄	392.00	pa	
B		415.30	D	
W	A ₄	440.00	dha	
B		466.16	N	
W	B ₄	493.88	ni	
W	C ₅	523.25	sa'	Tar
B		554.37	R'	
W	D ₅	587.33	re'	
B		622.25	G'	
W	E ₅	659.26	ga'	
W	F ₅	698.46	ma'	
B		739.99	M'	
W	G ₅	783.99	pa'	
B		830.61	D'	
W	A ₅	880.00	dha'	
B		932.33	N'	
W	B ₅	987.77	ni'	



particular, the huge popularity of harmonium across musical genres) the difference has all but disappeared. Therefore, for the sake of convenience, we shall use the ETS even while talking about the Indian scales and notes in this article.

As has been mentioned before, a *saptak* corresponds to an octave. Three main *saptaks* are used in Indian music. Unlike Western music, which has an absolute frame of reference, the Indian system changes from instrument to instrument. The middle register, referred to as the *madhya saptak*, uses a base note that is most comfortable for a particular musician (vocal or instrument); everything else is reckoned from here. The octave above this base is referred to as the *tar saptak*; the lower one is known as the *mandra saptak*. Additionally, two octaves above the middle is called *ati-tar saptak*; three octaves above is called *ati-ati-tar saptak* and so on. The reed instruments also allow us to connect the Indian *saptaks* with the corresponding octaves of an ETS in an easy manner, as shown in *Table 2*. It is also clearly seen how the Indian scale corresponds to the ‘major’ scale, since the pure tones of a *saptak* follows the ‘T T S T T T S’ pattern.

The three main *saptaks* of the Indian tradition are the *mandra*, *madhya* and *tar saptak*.

2. Shifting the Scale

One of the main characteristic differences between Western classical music and Indian is in their approach to fixing the *tonic* or the *base note*. In the Western tradition, as we have seen earlier, a particular piece of music is set for a particular scale (the home octave, inclusive of all the notes), and the instruments are tuned to play those specific frequencies. On the other hand, Indian music is, more or less, independent of the chosen home octave. A performer can choose the base note (*sa*) of the *madhya saptak* (or more precisely, the home octave) according to her/his convenience and, therefore, effectively has infinite freedom in doing so. Indeed, traditional Indian music makes use of the infinite possibilities accorded by the frequency continuum. This freedom is enjoyed by the vocalists and also, to some extent, by the musicians using string instruments. However, for reed instruments the



Table 3. Illustration of *scale change* — When the base note is moved (by a particular multiplicative factor) keeping the octave structure intact, it shifts all the notes in the entire scale exactly by the same multiplicative factor.

Note	ν Hz	C Major	F Major	A Major	B _{Flat} Major
C ₂	65.406	<i>sa</i> _\			
	69.296	<i>R</i> _\			
D ₂	73.416	<i>re</i> _\			
	77.782	<i>G</i> _\			
E ₂	82.407	<i>ga</i> _\			
F ₂	87.307	<i>ma</i> _\	<i>sa</i>		
	92.499	<i>M</i> _\	<i>R</i>		
G ₂	97.999	<i>pa</i> _\	<i>re</i>		
	103.83	<i>D</i> _\	<i>G</i>		
A ₂	110.00	<i>dha</i> _\	<i>ga</i>	<i>sa</i>	
B _{flat}	116.54	<i>N</i> _\	<i>M</i>	<i>R</i>	<i>sa</i>
B ₂	123.47	<i>ni</i> _\	<i>ma</i>	<i>re</i>	<i>R</i>
C ₃	130.81	<i>sa</i>	<i>pa</i>	<i>G</i>	<i>re</i>
	138.59	<i>R</i>	<i>D</i>	<i>ga</i>	<i>G</i>
D ₃	146.83	<i>re</i>	<i>dha</i>	<i>ma</i>	<i>ga</i>
	155.56	<i>G</i>	<i>N</i>	<i>M</i>	<i>ma</i>
E ₃	164.81	<i>ga</i>	<i>ni</i>	<i>pa</i>	<i>M</i>
F ₃	174.61	<i>ma</i>	<i>sa'</i>	<i>D</i>	<i>pa</i>
	185.00	<i>M</i>		<i>dha</i>	<i>D</i>
G ₃	196.00	<i>pa</i>		<i>N</i>	<i>dha</i>
	207.65	<i>D</i>		<i>ni</i>	<i>N</i>
A ₃	220.00	<i>dha</i>		<i>sa'</i>	<i>ni</i>
	233.08	<i>N</i>			<i>sa'</i>
B ₃	246.94	<i>ni</i>			
C ₄	261.63	<i>sa'</i>			

change of the home octave would necessarily be discrete. In the following, we shall discuss two different cases of this *shift* (both based on the discrete ETS) commonly made use of in Indian music.



2.1 Scale Change

The simple *shift* of the home octave (popularly known as the **scale change** in India) is just that. The change of the base note from one frequency to another one, keeping the structure of the *saptak* intact. Remember, we have twelve *swaras* to the *saptak* corresponding to the twelve steps of an ETS, the frequency of a particular *swara* being $2^{\frac{1}{12}}$ higher than the one immediately preceding it. Table 3 illustrates the *scale change* for a reed instrument. For vocalists accompanied by harmonium, the scales spanning G_2-B_2 are quite popular in modern Indian music. Typically, male voices prefer scales with a higher frequency base note compared to those preferred by female voices, signifying the natural pitch(frequency) difference between male and female voices. Of course, there exist a huge range of natural frequencies at which a particular vocalist is comfortable. For example, there are people who feel most comfortable to sing at F_2 implying that the natural frequency of their voice is a factor of $2^{\frac{6}{12}}$ (≈ 1.414) lower than the natural frequency of someone singing at B_2 .

Interestingly, likely due to its huge popularity across musical genres in India, the harmonium has now been modified to incorporate a scale-changing mechanism. Using this, one can move from a scale (say F) to another (say B) without having to experience a change in the piano keys. The harmonium player is then able to use the same fingering (that s/he is used to) for all the shifts in home octave with the scale-changing mechanism of the instrument taking care of the shift in frequency rather than a change in keystrokes.

A scale-change is a simple shift in the base frequency, without any change in the structure of the music.

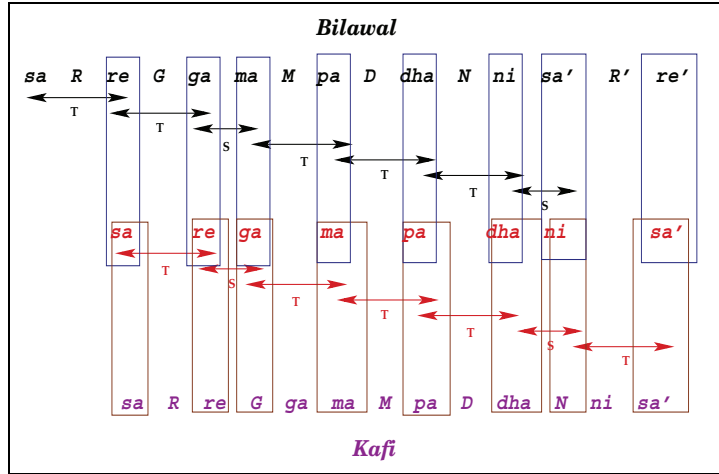
Murchhana or *grahabhedam* is a way of changing the scale which alters the basic scale structure or *thaat*.

Table 4. Illustration of *Murchhana*. Only *Hindustani* names of the *ragas* are indicated. See text for an explanation.

<i>Bilawal</i>	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*	*	*	*	*	*
<i>Kafi</i>	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*	*	*	*	*
<i>Bhairavi</i>	*	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*	*	*	*
<i>Kalyan</i>	*	*	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*	*	*
<i>Khammaj</i>	*	*	*	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*	*
<i>Asavari</i>	*	*	*	*	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>	*
—	*	*	*	*	*	*	<i>sa</i>	<i>re</i>	<i>ga</i>	<i>ma</i>	<i>pa</i>	<i>dha</i>	<i>ni</i>	<i>sa'</i>



Figure 1. Application of the rules of *Murchhana* to obtain *Raga Kafi* from *Raga Bilawal*.



2.2 Murchhana

On the other hand, there is a more complex, and far more profound change of scale that is known to Indian classical music. This is known as *murchhana* in Hindustani (North Indian) classical and as *grahabhedam* in Carnatic (South Indian) classical tradition. Evidently, the Carnatic name gives away the underlying logic behind this – *graha* means ‘position’ and *bhedam* means ‘change’. The process literally means a ‘change of position’. Indeed at a first glance, it appears to be no more than a shift of the base note and all the subsequent notes as shown in *Table 4*³. However, this looks completely counter-intuitive. We have just seen that the Indian music allows for any shift of the home octave. By that argument, this shift is not likely to produce anything new. On the other hand, we also know that each *raga* has its own specific set of *swaras* which gives it a particular flavour specific to that *raga*. Yet, we are moving from one particular *raga* to another, simply by shifting the *saptak* by a number of *swaras* according to this prescription. Neither of these are satisfied if we consider this table naively. Nor is it clear why the last shift indicated in the table is not an extant *raga*.

Here, we need to remember that the *shuddha swaras* or the pure tones are not equidistant (in a logarithmic sense) on an ETS. But

³The corresponding Carnatic names of the *ragas* are – Dhirashankarabaranam (Bilawal), Kharaharapriya (Kafi), Hanumantodi (Bhairavi), Mechakalyani (Kalyan), Harikamboji (Khammaj), Natabhairavi (Asavari).



if all the 12 tones (*shuddha* + *vikrita*) are taken together, then they give us 12 equidistant notes. Whenever we map a set of 7 *shuddha swaras* to another set of 7 *shuddha swaras*, we are not performing a fixed frequency shift (as was the case earlier, for a simple ‘scale-change’) but something far more complicated. Consider *raga Bilawal* which is characterised by a pure *saptak*, i.e., by all of the seven *shuddha swaras*. Since, Indian *saptak* corresponds to a major scale of the Western tradition, the notes are separated

Figure 2. Application of *Murchhana* through the entire *saptak*. Legends: *sp* – *saptak*, *es* – *extended saptak*, *sw* – *swara*, *ss* – *shifted saptak*.

<i>bilawal</i>		<i>kafi</i>		<i>bhairavi</i>		<i>kalyan</i>		<i>khamaj</i>		<i>asavari</i>		—	
<i>sp</i>	<i>es</i>	<i>sw</i>	<i>ss</i>	<i>sw</i>	<i>ss</i>	<i>sw</i>	<i>ss</i>	<i>sw</i>	<i>ss</i>	<i>sw</i>	<i>ss</i>	<i>sw</i>	<i>ss</i>
<i>sa</i>	<i>sa</i>	-	--	-	-	-	-	-	-	-	-	-	-
-	<i>R</i>	-	--	-	-	-	-	-	-	-	-	-	-
<i>re</i>	<i>re</i>	<i>sa</i>	<i>sa</i>	-	-	-	-	-	-	-	-	-	-
-	<i>G</i>	-	<i>R</i>	-	-	-	-	-	-	-	-	-	-
<i>ga</i>	<i>ga</i>	<i>re</i>	<i>re</i>	<i>sa</i>	<i>sa</i>	-	-	-	-	-	-	-	-
<i>ma</i>	<i>ma</i>	<i>ga</i>	<i>G</i>	<i>re</i>	<i>R</i>	<i>sa</i>	<i>sa</i>	-	-	-	-	-	-
-	<i>M</i>	-	<i>ga</i>	-	<i>re</i>	-	<i>R</i>	-	-	-	-	-	-
<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>ma</i>	<i>ga</i>	<i>G</i>	<i>re</i>	<i>re</i>	<i>sa</i>	<i>sa</i>	-	-	-	-
-	<i>D</i>	-	<i>M</i>	-	<i>ga</i>	-	<i>G</i>	-	<i>R</i>	-	-	-	-
<i>dha</i>	<i>dha</i>	<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>ma</i>	<i>ga</i>	<i>ga</i>	<i>re</i>	<i>re</i>	<i>sa</i>	<i>sa</i>	-	-
-	<i>N</i>	-	<i>D</i>	-	<i>M</i>	-	<i>ma</i>	-	<i>G</i>	-	<i>R</i>	-	-
<i>ni</i>	<i>ni</i>	<i>dha</i>	<i>dha</i>	<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>M</i>	<i>ga</i>	<i>ga</i>	<i>re</i>	<i>re</i>	<i>sa</i>	<i>sa</i>
<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>N</i>	<i>dha</i>	<i>D</i>	<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>ma</i>	<i>ga</i>	<i>G</i>	<i>re</i>	<i>R</i>
-	<i>R'</i>	-	<i>ni</i>	-	<i>dha</i>	-	<i>D</i>	-	<i>M</i>	-	<i>ga</i>	-	<i>re</i>
<i>re'</i>	<i>re'</i>	<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>N</i>	<i>dha</i>	<i>dha</i>	<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>ma</i>	<i>ga</i>	<i>G</i>
-	<i>G'</i>	-	-	-	<i>ni</i>	-	<i>N</i>	-	<i>D</i>	-	<i>M</i>	-	<i>ga</i>
<i>ga'</i>	<i>ga'</i>	-	-	<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>ni</i>	<i>dha</i>	<i>dha</i>	<i>pa</i>	<i>pa</i>	<i>ma</i>	<i>ma</i>
<i>ma'</i>	<i>ma'</i>	-	-	-	-	<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>N</i>	<i>dha</i>	<i>D</i>	<i>pa</i>	<i>M</i>
-	<i>M'</i>	-	-	-	-	-	-	-	<i>ni</i>	-	<i>dha</i>	-	<i>pa</i>
<i>pa'</i>	<i>pa'</i>	-	-	-	-	-	-	<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>N</i>	<i>dha</i>	<i>D</i>
-	<i>D'</i>	-	-	-	-	-	-	-	-	-	<i>ni</i>	-	<i>dha</i>
<i>dha'</i>	<i>dha'</i>	-	-	-	-	-	-	-	-	<i>sa'</i>	<i>sa'</i>	<i>ni</i>	<i>N</i>
-	<i>N'</i>	-	-	-	-	-	-	-	-	-	-	-	<i>ni</i>
<i>ni'</i>	<i>ni'</i>	-	-	-	-	-	-	-	-	-	-	<i>sa'</i>	<i>sa'</i>
<i>sa''</i>	<i>sa''</i>	-	-	-	-	-	-	-	-	-	-	-	-



by a 'T T S T T T S' pattern, where T stands for a tone (factor of $2^{\frac{2}{12}}$) and S stands for a semi-tone (factor of $2^{\frac{1}{12}}$). This is illustrated in *Figure 1*. Now, let us follow the prescription given in *Table 4* and move the *swaras* by one position to obtain *raga Kafi*. Note that the *swaras* of the shifted *saptak* are separated by 'T S T T T S T' pattern (second row of the figure). According to the Western definition, it is no longer a major scale. However, the Indian *saptak* adheres strictly to the major scale. Therefore, if we define a major scale or a true *saptak* with the shifted base note (*sa*) we obtain the pattern given by the third row in *Figure 1*. Comparing the second and the third row of the figure, it is easy to see that instead of all the *shuddha swaras* of *raga Bilawal*, now we have two *vikrita swaras* (namely, G, N) for *raga Kafi*.

This is how a new *raga* is created by shifting the base note in Indian tradition and is known as *murchhana*. The process is illustrated for the entire *saptak* in *Figure 2*. It needs to be noted that for all the shifts, barring the last one, *pa* remains a *shuddha swara*. As it should be, because in Indian tradition *sa* and *pa* are the two notes that do not have any variant (and *pa* is actually the 'fifth' of the Pythagorean scale). Since this condition is not satisfied in the last shift (*pa* is shifted to M here) it is not considered to be a valid *raga*.

Of course, Indian classical genre is not confined to just these six *murchhanas* or six *ragas*. A multitude of new *ragas* can be created remembering that traditional Indian scale consists not seven but, at least 22 *shrutis* (or more). Also, it is not mandatory to have 7 base notes, a *raga* can also be constructed with a lesser number of base notes. Rather complex theories of music exist (differing significantly from one side of the Vindhya to the other) that deal with the family of this large number of extant *ragas*. However, for the uninitiated, understanding this simple yet elegant logic underlying the *sounds of music* of the *ragas* appears to be a beautiful exercise in itself.

A *murchhana* that shifts the *atal swar* 'pa' is not allowed.



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Suggested Reading

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