Musical Scale

Musical scale consists of series of notes having certain relation to one another as regards the frequency of vibration . The human ear can distinguish a number of notes of definite frequencies between a note and its octave.The note of lowest frequency at such a series called ***key note or tonic***. The building up of a musical scale is based on two assumptions about the human hearing process:

- The ear is sensitive to ratios of frequencies (pitches) rather than to differences in establishing musical intervals.
- The intervals which are perceived to be most consonant are composed of small integer ratios of frequency.

Musical Interval: The ratio of frequencies between two notes in the musical scale is known as **musical intervals**.The term musical interval refers to a step up or down in pitch which is specified by the ratio of the frequencies involved. For example, an **octave** is a music interval defined by the ratio 2:1 regardless of the starting frequency. From 100 Hz to 200 Hz is an octave, as is the interval from 2000 Hz to 4000 Hz. The intervals which are generally the most consonant to the human ear are intervals represented by small integer ratios. Intervals represented by exact integer ratios are said to be Just intervals, and the temperament which keeps all intervals at exact whole number ratios is Just **temperament**.
For example, in the buildup of a pentatonic scale by a circle of fifths, a natural whole tone of ratio 9/8 emerges, satisfying the condition for consonance. A semitone like E-F also emerges, and the ratio 256/243 suggests dissonance. **Fig.**(1)*and*(2)

Ratio	**Interval**
1 : 1	unison
2 : 1	octave
3 : 2	fifth
4 : 3	fourth
5 : 4	major third
5 : 4	minor third
5 : 3	major sixth
6 : 3	minor sixth

Chord: When two or more notes sounded together then chord is said to be produced.
Concord and Consonance: When two or more notes sounded together and the combination produces pleasing effect to the ear than it is said to be **concord** and the notes are said to be **consonance**.But if they produce unpleasant effect to the ear than it is said to be **Discord** and notes are said to produce **Dissonance**. he simplest approach to quantifying consonance is to say that two

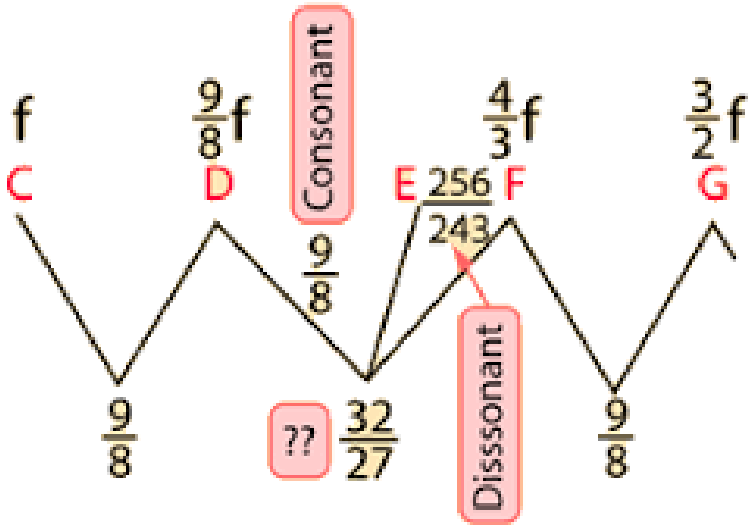

Figure 1: Musical scale and interval

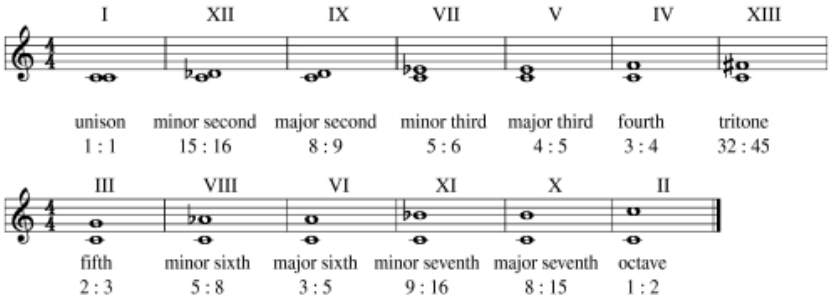

Figure 2: Musical scale and interval

Figure 3:

tones are consonant if their frequencies are related by a small integer ratio. The ratio determines the musical interval. The octave $2:1$, fifth $3:2$, and fourth $4:3$ are presumed to be universally consonant musical intervals

Harmonic triad: Any three notes within the musical scale whose frequencies are in the ratio $4:5:6$ are said to be harmonic triad.

Major chord: A harmonic triad together with an octave to the lower, constitute a major chord.

Minor chord:Any three notes whose frequencies are in the ratio $10:12:15$ when sounded together are slightly dissonance. These three notes with the octave to the lower, constitute minor chord.

Harmony and melody: When two or more notes sounded together the pleasing effect due to the concord is known as ***harmony*** while the succession of notes producing a pleasing sensation is known as ***melody***;. The musical scale notes should be of such notes so that they are able to produce both harmony and melody.

The equal tempered scale is the common musical scale used at present, used for the tuning of pianos and other instruments of relatively fixed scale. It divides the octave into 12 equal semitones **Fig.(3)**. It is common practice to state musical intervals in cents, where 100ζ is defined as one equal tempered semitone. The cents notation provides a useful way to compare intervals in different temperaments and to decide whether those differences are musically significant. A useful parameter for comparison is the just noticeable difference in pitch which corresponds to about 5ζ. Equal tempered scale is same in any musical key.

Helmholtz Theory of Consonance and Dissonance

For two complex tones in unison ($P:Q=1:1$) or an octave apart ($P:Q=1:2$), all harmonics of the second tone are aligned and coincident in frequency with the first, and thus the outcome is highly consonant. However, as the frequency ratio P:Q becomes more complicated, the two tones share fewer common harmonics, while there is an increase of harmonic pairs slightly mismatched in frequency. According to Helmholtz's (1877) linear theory, these latter nearby harmonics interact and lead to an unpleasant beating sensation that results in dissonance.

The beating effect may be expressed mathematically as taking the sum of two pure sine tones having almost the same frequencies and both of the same

amplitude.

$$sin(\omega_1 t) + sin((\omega_1 + \delta)t)) = 2cos(\frac{\delta t}{2})sin(\bar{\omega}t), \quad (1)$$

Where $\bar{\omega}$ is the average frequency. Thus, a listener will not have the impression of listening to two different frequencies but instead will hear a single pure tone with a pitch corresponding to the average frequency $\bar{\omega}$ and with loudness that varies slowly leaving a beating sensation oscillating with an envelope at frequency δ=$\omega_2 - \omega_1$

Types of Musical Scale

There are two type of musical scale

- **Diatonic scale**

  It consist of eight notes. The interval between the eighth and the first is 2 : 1. They are divided into suitable smaller intervals as to produce melody when tones are successively sounded. Melody is produced between any two tones while going from lowest to the highest of the frequencies or from highest to the lowest.

Symbol	Western name	Indian name	proportional freq.	Freq. (256) , Interval
C	Do	Sa	24	256, $\frac{9}{8}$Major
D	RE	Re	27	288 , $\frac{10}{9}$Minor
E	MI	Ga	30	320 , $\frac{16}{15}$Limma
F	FA	Ma	32	341.3 , $\frac{9}{8}$
G	SOL	Pa	36	384, $\frac{10}{9}$
A	LA	Dha	40	326.7 , $\frac{9}{8}$
B	SI	Ni	45	480 , $\frac{16}{15}$ Semitone
Ci	do	Sa	48	512 ,

  The lowest of the tones is *Tonic* or *Key note* and the highest is called *Octave*. In music seven such octave extending on both sides of the Key note are required in lowest is taken from C to C_1 then C_1 to C_2 and the highest is from C_6 to C_7. Any other note is represented with the subscript to the octave to which it belongs.The interval between two successive frequencies in a diatonic scale are not equal. The defect of this scale is that it is not possible to change the tonic.

- **Tempered scale**

  In this scale the following consideration is taken into account.

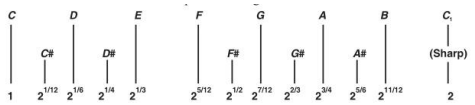

Figure 4:

- Possibility of changing tonic, where the large number of notes are slowly rising in pitch within the octave, will be necessary,
- Too many notes should not be included for sake of practical convenience.
- Dissonance should be avoided.

The adjusted scale is called tempered scale. Here the temperament divides the interval between the tonic and the octave into 12 equal intervals

If x is the interval between the two consecutive note then

$$x^{12}=2$$
$$\text{or, } x=2^{\frac{1}{12}}=1.05946$$

The white key in Piano or harmonium corresponds to original $CDEFGABC_1$ in diatonic scale $Fig.(4)$. The black key gives $C\sharp$ $D\sharp$ $F\sharp$ $G\sharp$ called C and D sharp etc.