Sharps and flats are quite natural

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A part of most societies is the sharing of songs, to be sung by individuals, a section or all of the community. Humans have the ability to learn the conventional scales of their communities on which their shared songs are based. These tend towards an upper limit of seven notes per octave which may be biologically imposed. Melodies with an octave density greater than seven may be recognised but tend not to be spontaneously sung or whistled with accuracy by people with average abilities without specialist training, note labels, notation etc. This is not to suggest there is a a boundary to human imagination or to the abilities of exceptional individuals.

A scale is usually repeated in octaves. Melodies repeated at an octaves distance are considered to be in tune. This enables the whole comminuty to participate irrespective of age and gender. A community may use several scales to choose from. New scales can arise beause of social turmoil, (e.g. the blues scale), foreign influence or simply fashion.

Early stringed intruments often had seven frets per octave. This number is still used in the Appalachian mountain dulcimer. It can be seen and heard that some scale steps are larger than others. It can also be observed the the spacing of the scale steps over the octave is assymetrical which subconciously helps singers to orientate themselves. The lutenists around 1500 started to fill in the gaps with five extra frets probably so as to be able to play passable major and minor triads on all of the seven main notes. This produced a density of twelve notes per octave. It is notable that the spacing of the five inbetweens make a pentatonic scale that is also assymetrical.

The process of filling in the gaps had already been taking place in church organ design which started with seven white notes per octave. The black notes were gradually introduced to reach the present layout around 1350. The inbetween notes were described as flattening or sharpening of the main seven, a procedure that can be described as the *elastic heptatonic*. However the sustained sound of the organ encouraged organ builders to avoid any deviation from simple ratios between the length of pipes (temperament) which produces audible beats . It is not possible to retain simple ratios and keep a uniform semitone between all seven white and five black notes so some intervals were favoured over others.

It is much easier and cheaper to make tuning adjustments on the lute which had moveable frets made from gut. The fret passes beneath six strings tuned mostly a perfect fourth apart with one major third producing five different notes the outer strings being two octaves apart. This encouraged the players to make a compromise of equal intervals between the twelve frets finding that reducing the

string length by 1/18th with each fret produced a workable result. The resulting spacing, equal temperament[1] , was adopted in the succeding centuries by all the instruments of the European orchestra, by vocalists , and eventually even by the organ. It countinues its journey through out the world - to the regret of some musicologists who feel that local tuning characteristics are being eroded.

The lutenist may have simply been interested in producing passable major and minor chords on each of the seven main notes. However equally spaced semitones offered new possibilities:

By 1567 Gorzanis had produced a suite of pieces in early versions of major and minor keys on all the twelve frets[2]. It is notable that Gorzanis was blind since birth and the pieces were written in fret numbers (lute tablature) and not transcribed into elastic heptatonic until the 20th century.

- slow chromatic basslines in slow tempo were particularly associated with the expression of grief.
- Modulating between keys became easier and became a common feature of musical design from the 1600s.
- With the semitones now uniform it was possible to form all major and minor keys into a circle of perfect fifths (7 semitones). In 1728 a harmony treatise has a diagram of the major and minor keys arranged in a circle. It demonstrates the circle with a piece that starts in A minor and modulates by fifths through the entire cycle to return to A minor[3].
- The inbetween notes came to be used for local decoration (passing notes, neighbour notes etc.)
- As the semitones were now equal they could be used as units of measurement. In 1885 Alexander Ellis's curiosity about cultures that were not using equal temparament led him to divide the semitone into 100 parts (the cent) for accurate description[4]. It would be interesting to see how many of the scales Ellis described have survived the exposure to equal temperament via modern media.
- The twelve semitone options could approximate some scales from outside Europe . They can accomodate, if not exactly, the Ragas of northern India and the equally tempered harmonion often used in vocal performance and training.

The semitones make passable approximations of the harmonic series up to the 10th harmonic, close enough to contribute to the root sensation of chords[5].

- As 12 has several factors, 2, 3, 4 and 6 interest grew in creating symmetrical scales and chords. Being symmetrical the listener loses orientation within the octave. Symmetrical scales are often associated with mystery, magic, transition and otherworldliness.
- In the early 20th Century the dodecaphonic school explored the systematic usage of all twelve notes.

The same inbetween note may have several different histories according to its context, sometime regarded as a sharpened note, sometimes a flattened one, sometimes both at the same time. Such alternative histories are called *enharmonic equivalents* in music theory. Sometimes a composer will start by describing a note as a flat and change its description to a sharp while it is still being held [6]. Sometimes the inbetween note may be not actually be experienced as sharpening of a flatten of one of its neighbours but still be described as such for convenience or for want of anything better. The choice between the contenders maybe based on convention, fashion[7], whim or consideration for the reader. The A natural in the second bar of Debussy's Clair de Lune is widely experienced as flattening but B double flat may have appeared uninviting and pedantic.

Despite the increased possibilities of twelve equal semitones the octave density in the performance of communal vocal music and much intrumental music still tends towards seven.

Middle Eastern fretted instruments sometimes offer the option of seventeen notes per octave (though unequally spaced) while sung melodies rarely use more than seven of these at a time at a time.

The scalar history of a note is quickly lost on some instruments such as the trumpet. The violin and viola players preserve the history in their fingers which are placed on the strings modelling a fragment of the seven note layout of the frets of the Appalacian dulcimer. They can can of course shift their fingers to reshape the scale as required.

However the sound is produced the scalar history is lost when sound fills the air. Each listener will, consciously or unconsciously, attempt to recreate their own individual scalar history of the piece - which may or may not correspond with the composer's or performer's. If the piece uses an octave density greater than seven the listener may abandon the recreation of scalar history. An increased density may also create a feeling of unease and disorientation. This is widely used by film composers to create tension. The title themes, on the other hand, which they would like the public to remember and perhaps sing or whistle, tend to have an octave density of around seven or less.

There is no guarantee that the written scalar history will be recreated by the listener. For example pop songs often introduce a semitone key shift to heighten drama. A song starting in C would then move to the key of Db, whereas the listener will feel an uplift, better represented by C# major. Though C# major was used by Bach, it is now out of fashion, for the merely practical reason that it uses five flats rather than seven sharps. Some of Gorzini's pieces beginning on all 12 frets, when transcribed into elastic heptatonic, will inevitably start on sharpend or flattened notes. This is not what we experience on hearing the begining of the piece

and is merely a byproduct of transcription.

Many designers of of instruments, notation and nomenclature have sought to put the twelve semitones on an equal footing. These ideas are can be perused at www.musicnotations.org.

Why might an octave density of seven tend to be an upper limit for spontaneous imitation? A community needs a limited number of conventional stations on the continuum of muscular tension of the vocal chords. Seven allows for a spread of notes such that the voice can move from one to the next easily without being so close that they are hard to distinguish, in the same way that vowel resonances need to be close for access but not so close as to become confusable.

We may also use the unconcious memory of the harmonics of recently heard notes as a guide to singing the next note. Notes a semitone apart share none of the first ten harmonics, those most audible to the ear. Larger intervals, 2nds, 3rds, 4ths and 5ths, are more likely to have harmonics that coincide or are very close. The unconcious guidance offered by recent harmonics is stable whether a song is sung in a high or low key. Adjacent semitones create a feeling of tension as in the centre of the blues scale and in the Neapoliton chord and its resolution (e.g. the closing bars of Lionel Ritchie's *Hello*).

When the number of notes increases beyond seven we may first prefer to perceive that one of a limited number of scale notes has shifted rather than a new note has been added to the scale.

To conclude it may be useful to sketch a list of the main features of the mapping of sound, hearing, muscles and instruments in relation to equal temperament:

Audio . Sound waves a semitone apart are indifferent to note name and octave.

The voice : the muscular tension between low and high notes is indifferent to scale note and octave and can only be tuned with reference to the sound. This is similar to the muscular tension used in playing the musical saw.

Whistling: the pitch is varied by the tongue muscles which are indifferent to scale note and octave: tuning depends on aural feed back.

Vowels : in forming vowels the lips and tongue produce resonant peaks (formants) on the harmonics of voice. The formants are not fixed frequencies but relative to the size of the mouth, childrens, womens or mens. The maximum static vowels is around twenty.

Speech tones: About half the languges spoken today use voice pitch as word identifiers. These are not fixed pitches but are spread over the indivuals range, whether child, female or male. Tones have a maximum of around six.

The ear: The layout of the cochlea is specific to register but indifferent to scale note and octave, which are probably dependant on higher processing. Those with perfect pitch, about 1 in 10,000, develop recognition of notename, some so acute they they are disturbed if the tuning varies from what they originally learned.

Elastic heptatonic (traditional notation and nomencalture) Seven notes assymetrically spaced notes are sharpened or flattened to describe inbetween notes, a scheme reflected in note names and notation. In equal temperament they are sharpened and flattened by the same amount to offer competing descriptions of the five inbetweens. The note names are octave-general though may be localised by suffixes eg C4 (middle C). The stave corresponds to frequency but is indifferent to scale members and their octave repetitions, both of which must be learned or deduced.

Lute, guitar etc: frets are a semitone apart but are indifferent to scale note and octave which must be learned or deduced. Their tablature counts frets along individual strings and is also indifferent to note name and register.

The keyboard: having separate levers each semitone of equal temperament but retaining the historical derivation seven of scale notes and five inbetweens. It does not show register.

Flutes and whistles: six or seven finger holes producing the heptatonic scale is an extremely ancient design. The scale is duplicated an octave above byoverblowing. Inbetween notes can be obtained by half closing the holes or by levers.

MIDI represents each ascending semitone by a different number. It is specific to register but indifferent to notename and octave which must be learned or deduced. MIDI notes can be further microtuned.

Footnootes

1. A semitone was defined as the twelfth root of two by Simon Stevin in 1585. A similar definition was arrived at in 1584 by Zhu Zaiyu. It is intriguing how the lutenists, European and Chinese mathemetics arrived independently at a similar result within a few decades of each other. However there is suggestion that equal temperament may have been developed as early as 2697 B.C.E. so that the Chinese Emporer Huang Ti could allow a pentatonic scale to migrate round the "cycle of fifths". This is described in *Music in the Age of Confucius* by Jenny F. So. Smithsonian Institute 2000. This book was reviews by Tom Reed in Music Notation News 1st Qarter of 2001. There is also a detailed article on equal

temperament on Wikipedia.

2. Libro di Intaulatura di Lauto 1567 edited by Bruno Tonazzi, Edizioni Suvini Zerboni – Milano 1975. Also Ein Tanzzyklus des 16.Jahrhunders fur Laute von Giacomo Gorzanis. Edited by Issam El-Mallah Verlegt bei Hand Schneider 1979. This edition contains the orginal tablature. In recent times attention was first attrcted by Merman Halbig "Eine handschriftliche Lautentablatur des Giacomo Gorzanis. Theodor Kroyer-Festscrift (Regensburg, 1933), pp. 102-112. A cycle with the same 24 part design was circulated in tablature by Vincenzo Galilei in 1584.
3. Johann David Heinichen *Der General-Bass in der Composition*
4. Alexander J. Ellis *On the Musical Scales of Various Nations* Journal of the Royal Society of the Arts 1885 Vol. XXXIII.
5. Ernst Terhardt *Psychoacoustic evaluation of musical sounds* Perception and Psychophysics 1978, Vol.23 (6) , 483-492
6 e.g. Chopin 1st Mazurka from the 10th set Op.59 at 2nd change of keysignature.
7 A common chord symbol in jazz is C7 #9. It was earlier referred to as C7 ♭10.