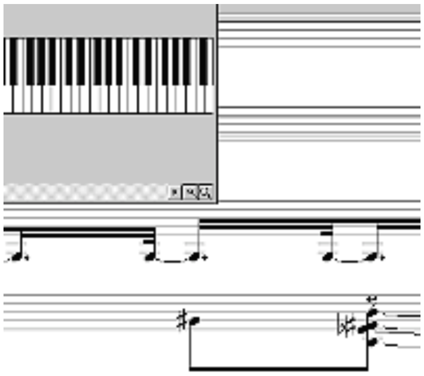
Striking the right Note



Perfect pitch is a rare talent possessed solely by the likes of Beethoven, Frank Sinatra and Ella Fitzgerald, right? Wrong, as Kathryn Brown discovers, it's turning up all over the place

ELIZABETH WEST MARVIN can always tell which music students have perfect pitch. They don't necessarily play any differently from her other students, and they may not always lead the chorus. But they are the ones who immediately get distracted when the fluorescent lights above their heads start vibrating with an electrical hum somewhere between B and B-flat.

The uncanny, if sometimes distracting, ability to name a solitary note out of the blue, without any other notes for reference, is a prized musical talent-and a scientific mystery. Musicians with perfect pitch-or, as many researchers prefer to call it absolute pitch-can often play pieces by ear, and many can transcribe music brilliantly. That's because they perceive the position of a note in the musical stave-its pitch-as clearly as the fact that they heard it. Hearing and naming the pitch go hand in hand.

By contrast, most musicians follow not the notes, but the relationships between them. They may easily recognise two notes as being a certain number of tones apart, but could name the higher note as an F only if they are told the lower one is a C, for example. This is relative pitch. Useful, but much less mysterious.

For centuries, absolute pitch has been thought of as the preserve of the musical elite. Some estimates suggest that maybe fewer than 1 in 2000 people possess it. But a growing number of studies, from speech experiments to brain scans, are now suggesting that a knack for absolute pitch may be far more common, and more varied, than previously thought. "Absolute pitch is not an all or nothing feature," says Marvin, a music theorist at the University of Rochester in New York state. Some researchers even claim that we could all develop the skill, regardless of our musical talents. And their work may finally settle a decades-old debate about whether absolute pitch depends on melodious genes -or early music lessons.

Music psychologist Diana Deutsch at the University of California in San Diego is the leading voice. Last month at the Acoustical Society of America [Ref: Animals7:{Human capabilities of Echo removal}:Animals3 {Snap crackle and milli-pop}]meeting in Columbus, Ohio, Deutsch reported a study that suggests we all have the potential to acquire absolute pitch-and that speakers of tone languages use it every day. A third of the world's population-chiefly people in Asia and Africa-speak tone languages, in which a word's meaning can vary depending on the pitch a speaker uses. Deutsch and her colleagues asked seven native Vietnamese speakers and 15 native Mandarin speakers to read out lists of words on different days.The chosen words spanned a range of pitches, to force the speakers to raise and lower their voices considerably. By recording these recited lists and taking the average pitch for each whole word, the researchers compared the pitches used by each person to say each word on different days.

Both groups showed strikingly consistent pitch for any given word-often less than a quarter-tone difference between days. "The similarity," Deutsch says, "is mind-boggling." It's also, she says, a real example of absolute pitch. As babies, the speakers learnt to associate certain pitches with meaningful words-just as a musician labels one tone A and another B-and they demonstrate this precise use of pitch regardless of whether or not they have had any musical training, she adds.

Deutsch isn't the only researcher turning up everyday evidence of absolute pitch. At least three other experiments have found that people can launch into familiar songs at or very near the correct pitches. Some researchers have nicknamed this ability "absolute memory", and they say it pops up in other senses, too. In a 1994 study, for example, Svein Magnussen and Stein Dyrnes of the University of Oslo in Norway found an absolute memory for visual images, showing that people could pick out complex black-and-white line designs they had seen hours or days earlier from a selection of very similar ones.

Given studies like these, the real mystery is why we don't all have absolute pitch, says cognitive psychologist Daniel Levitin of McGill University in Montreal. "I don't have to run to a rainbow and find red to tell you that a tomato is red," Levitin says. "There are 10 basic colours that everyone can name immediately. Well, there are 12 basic pitches. If we can label all those colours, why can't we label all those pitches?" Levitin suspects he knows the answer. Absolute pitch, he says, is really a two-step process: pitch memory and pitch labelling. It's not that people with absolute pitch are genetically endowed with a keener sense of pitch perception, Levitin says-after all, many of us can recall a note nearly perfectly immediately after we hear it. But people with absolute pitch automatically connect the memory of a pitch with a label. Some even describe different pitches as having distinct "colours" or "characters".

Lacking absolute pitch, most of us can't make that connection-labelling a note as "D", for example. But do the connections and labels get hammered in during music lessons, or are some babies just born with a flair for identifying pitch? That's a hard question to answer, since musical parents often pass a passion for music-as well as their genes-on to their children.

Over the past decade, researchers have confirmed that absolute pitch often runs in families. Nelson Freimer of the University of California in San Francisco, for example, is just completing a study that he says strongly suggests the right genes help create this brand of musical genius. Freimer gave tone tests to people with absolute pitch and to their relatives. He also tested several hundred other people who had taken early music lessons. He found that relatives of people with absolute pitch were far more likely to develop the skill than people who simply had the music lessons. "There is clearly a familial aggregation of absolute pitch," Freimer says.

Blossoming talent

Freimer says some children are probably genetically predisposed toward absolute pitch-and this innate inclination blossoms during childhood music lessons.

Indeed, many researchers now point to this harmony of nature and nurture to explain why musicians with absolute pitch show different levels of the talent. "The early learning period-from about three to six years of age-is critical" says Marvin. But lucky genes probably help, she adds. Indeed, researchers are finding more and more evidence suggesting music lessons are critical to the development of absolute pitch. In a survey of 2700 students in American music conservatories and college programmes, New York University geneticist Peter Gregersen and his colleagues found that a whopping 32 per cent of the Asian students reported having absolute pitch, compared with just 7 per cent of non-Asian students. While that might suggest a genetic tendency towards absolute pitch in the Asian population, Gregersen says that the type and timing of music lessons probably explains much of the difference.

For one thing, those with absolute pitch started lessons, on average, when they were five years old, while those without absolute pitch started around the age of eight. Moreover, adds Gregersen, the type of music lessons favoured in Asia, and by many of the Asian families in his study, such as the Suzuki method, often focus on playing by ear and learning the names of musical notes, while those more commonly used in the US tend to emphasise learning scales in a relative pitch way. In Japanese preschool music programmes, he says, children often have to listen to notes played on a piano and hold up a coloured flag to signal the pitch. "There's a distinct cultural difference," he says.

If the right genes and music lessons do prompt people to label tones in a fundamentally different way, then this cognitive difference should show up in their brains. As indeed it does. In a 1998 study neuroscientist Robert Zattorre of the Montreal Neurological Institute in Canada ran positron emission tomography (PET) scans of musicians with and without absolute pitch while they listened to tones.

When asked to label a tone, the musicians lacking absolute pitch had a flash of brain activity in the right frontal cortex-an area associated with working memory and comparing incoming sensory information with memories. By contrast, the musicians who had absolute pitch could identify tones without accessing working memory at all. Instead, they showed a spark of brain activity high in the left frontal cortex-a region related to long-term memory. Zattore suggests that the absolute pitch users were tapping into a more deeply ingrained pitch template that they developed during childhood lessons.

A study led by musicologist Laura Bischoff of Shepherd College in West Virginia also shows that people with the strongest absolute pitch skills can name notes without working memory. Bischoff and her colleagues gave 32 music students-half of whom had absolute pitch-a series of tone tests while the students wore a jumble of scalp electrodes. The researchers were looking for a working memory marker: the P300, a positively charged waveform that flashes across the brain 300 milliseconds after a surprising stimulus. The P300 is thought to indicate a comparison of incoming sensory stimuli-such as a new tone-with memorised information, in this case a musical scale.

During one test, the students listened to a typical scale, trying to guess whether the note being played fitted within the scale. At first, the notes would build predictably, neatly forming a scale in the key of C. But then a tone would jump out of scale, falling unexpectedly flat or sharp. Scrambling to name that errant tone, the students without absolute pitch showed a P300 surge, as expected, while most of the students that had absolute pitch did not.

But the experiment also showed how varied a talent absolute pitch can be. Four of Bischoff's absolute pitch students showed brain wave patterns more like those in the control group. Further tests revealed that these absolute pitch students alternated between absolute and relative depending on the task at hand.

The lesson,Bischoff says, is that absolute pitch is not a one-fits-all talent. Some people have an acute sense of absolute pitch, while others show just a hint of the skill. And some absolute pitch possessors use it only occasionally, flipping back to relative pitch when that skill is more useful.

A bit of both

That doesn't surprise Philip Chang, a music theory graduate student at Rochester. While he's had absolute pitch since he was a child, Chang has also had training that hones relative pitch skills- practising scales, recognising intervals and so on. "I just use what's helpful," he says.

But can anyone develop absolute pitch? Bischoff thinks so. "Our studies tie right in with the idea that we all have this latent absolute pitch ability, but we can't get fully bloomed absolute pitch without early childhood training," says Bischoff.

But some scientists are more cautious. After all, if everyone remembered pitches, but just couldn't label them, we'd immediately know if something was played in an unusual key, or if two songs started on the same note, says psychologist Andrea Halpern of Bucknell University in Lewisburg, Pennsylvania. These feats, she says, are reserved for people with absolute pitch.

Similarly, linguists are wary of the idea that consistently speaking in a given pitch range somehow reflects absolute pitch. People naturally settle into a comfortable range while talking, says Rebecca Herman, a linguist at Indiana University. Deutsch counters that this "comfort zone" argument can't explain the exceedingly small differences in pitch among her speakers.

Indeed, Deutsch predicts that further studies will reveal absolute pitch-in its imperfect, latent form-inside all of us. The Western emphasis on relative pitch simply obscures it, she contends. "It's very likely that scientists will end up concluding that we're all born with the potential to acquire very fine-grained absolute pitch. It's really just a matter of life getting in the way."

Musical roots may lie in human voice

13:28 06 August 03 NewScientist.com news service

Key universal features in world music may have their roots in the ever-present sound of the human voice during the course of evolution, suggests a new study. The analysis of thousands of recorded speech samples found peaks in acoustic energy that precisely mirror the distances between important notes in the twelve-tone scale, the system that forms the foundation of almost all music. "The mysteries of music have a biologically principled explanation," says Dale Purves, at Duke University, North Carolina, and lead author of the study. "A reasonable speculation is that we hear these tonal relationships because they are involved in our interpretation of each other's speech." As a slide whistle shows, it is possible to change seamlessly the pitch of a sound from low to high and back again. But for making music, human cultures have sliced the pitch dimension into twelve distinct tones. This twelve-tone "chromatic scale" can be heard by starting at any piano key and then playing the next dozen white and black keys in succession. On the thirteenth note, the scale begins again, one octave higher.

Pythagoras's theorem

Different musical traditions have characteristic sound because many cultures have devised scales from a subset of the full chromatic scale, with different distances, or "intervals," between the tones. Chinese music is based on five-tone scales, while scales common in Western music have seven tones. But all cultures favour certain intervals from the chromatic scale, and listeners judge these same intervals to create the most harmonious combinations of two tones. Pythagoras proposed that such preferences could be predicted from mathematical relationships between tones, but these approaches have yet to provide a complete explanation. The Duke researchers randomly extracted over 100,000 speech samples, each 0.1 second long, from recordings of thousands of English sentences. Acoustic analysis of the combined samples revealed 10 frequency peaks that match the most significant intervals used in musical scales worldwide.

Mandarin and Farsi

Moreover, the relative heights of the peaks backed numerous studies in which listeners ranked the harmoniousness of intervals. Speech in other languages - Mandarin, Farsi, and Tamil - also displayed the same pattern. The frequency peaks are caused when a sound wave from the vocal cords is shaped by resonances of the throat and oral cavity. The researchers say that, aside from animal calls, speech emanating from oscillations of the human vocal cords is virtually the only natural sound that we hear as tones. This fact, combined with the new finding that preferred musical intervals are better predicted by the acoustic quirks of the human vocal tract than by mathematics, leads the scientists to argue that the structure of music is rooted in our long exposure to the human voice over evolutionary time. Journal reference: Journal of Neuroscience (vol 23, p 7160)

Peter Farley

Perfect pitch

Question In musical circles it is often claimed that the key or pitch of a piece can have a profound bearing on the mood conveyed. For example, if played in the key of E major, the music may be considered bright and powerful but in F major, peaceful or contemplative. This is surprising, given that all keys contain similar intervals when played in equal temperament. Few people have perfect pitch and the frequency shift in the above example is only one semitone, just under 6 per cent. It seems unlikely therefore that such an effect could be consistently experienced by a wide range of listeners. Have any tests been conducted, perhaps by simply playing recordings at different speeds and, if confirmed, what might be the physiological

basis?
John Allsop , Rayleigh Essex

Answers
Keys used to have distinctive characters, although these died out during the last century when the equal temperament tuning system became standard. A key's character is largely determined by the "major third", a musical interval between the pitch of two notes which appears in all common chords. Ideally, the frequencies should be in the exact ratio of 4:5. If they are, the pitches blend perfectly to produce a warm, mellow sound, and the interval is called a "natural third". A major third that is larger (sharper) than this, gives the key a bright character. If the major third is too small (flat), the key sounds dull. It is mathematically impossible to tune the major thirds of all keys to this ideal natural third--on average, major thirds have to be slightly sharp, as is the case in equal temperament. So in the past, only frequently used keys were tuned with natural thirds. As a consequence, the less common keys ended up with distinctly sharp major thirds, and rarely used keys were badly out of tune. Regardless of the tuning system used, the general result is the same. The commonest keys of C, F and G major have natural thirds and so sound mellifluous; Bb, D, Eb and A are neutral; E and Ab are bright to jangly and the remote keys of B, C# and F# make humans wince and dogs howl. This fits the questioner's descriptions of E and F major. Because of this effect, in the past composers allegedly chose keys to suit the character of the music. With equal temperament, however, all keys now have identical, neutral intervals, so this effect is lost.
Ben Finn , Cambridge

Until the 19th century, there really were differences between one key and another. Only in modern times has equal temperament given every musical key exactly the same intervals as any other. So in the past there may have been some objective basis for claiming different keys felt different. Nowadays this claim is purely subjective, although it may be influenced by a person's memories of other pieces of music in the same key, or by symbolic factors that are connected to factors other than sound--Mozart used Eb major as the masonic key, because it had three flats and three was the Freemasons' mystical number.
Peter Jeffrey , Music Department Princeton University

Even though most of us do not have perfect pitch, we can detect small differences in pitch when notes are played together or one after the other. The pitch of the stringed instruments can be varied infinitely, and these instruments often tend to play more closely to a natural scale than to the equal tempered scale that other instruments use. As the difference between the scales is less than 1 per cent, this effect does not make the instrument sound out of tune, but it affects the tonal quality of the whole orchestra when instruments of different kinds play together. To a certain extent, wind instrumentalists can also vary their pitch by varying the way they blow. However, the strings have some immutable notes: for example, the open strings on a violin are tuned to G, D, A and E. This means that some instruments play slightly out of tune, and the effect varies from key to key.
Terry Moore

"Absolute" pitch is irrelevant to the "colour" of various tonalities. If the only instrument available were a piano precisely tuned to 12 equally spaced semitones there would be little point writing music other than in C major because it would sound the same in any other key, only higher or lower. A wind instrument such as the recorder, on the other hand, uses a variety of "forked fingerings" for most of the semitones and is, in fact, a different instrument when played in C major or C# minor, for example. This is because the hand has too few fingers, and the recorder too few holes, to render all the semitones correctly and also because the tone (harmonics) of the instrument changes audibly from one forked fingering to another. It is to enhance these effects that good composers have exploited the built-in inequalities of tuning and tone of the various instruments.
J Azad , Calgary Canada

John Allsop is asking the wrong questions. By suggesting that few listeners would experience any change of musical colour as a result of a semitone pitch change, he is assuming that humans listen to (and play) music algorithmically, like a computer processing an incoming waveform. This is not the case. In fact, there are a great many factors which influence our perception of musical colour. If we consider the piano, the "shape" of a chord, its distribution of black and white notes and the position of the chord up or down the keyboard can have a considerable effect on the way it sounds. Some composers take advantage of this to achieve a particular tonal colour. Stringed instruments have fixed points in their range--when the strings are open. Certain keys are very much easier to play in than others, and resonance of the open strings plays a part in colouring keys. A further vital factor is the listener's cultural background. If we learn we are about to hear a work in C minor, we think of Beethoven's Third Piano Concerto or the Mozart Piano Concerto in that key--all are dark, tragic works. We presuppose that anything else in that key will be similar.
David Stater

As a young musician and composer I'm surprised never to have heard of this saying, and it's certainly not borne out that well by my experience. As part of music A-level I studied Bach's Brandenburg Concerto No 5 which is bright, happy and in F Major! I suspect that this saying refers to the fact that before the system of "equal temperament" was brought in, there was a slight difference between, for example, C sharp and D flat. Hence the scale in a "sharp" key (like E major) was slightly different to that of flat keys (like F major), and might account for the mood difference. With equal temperament (where C sharp and D flat are the same) this shouldn't apply, but composers would probably keep writing the same style in the same key, hence the relationship appears to stay.
Joe Wakeling , Monmouth

Until the early nineteenth century the use of different temperaments for tuning instruments meant that music did sound different when transposed to other keys, and composers consciously used these effects. Music was considered a science, whose physical and mathematical attributes were exploited from Pythagoras to Bach. More dubiously, theorists from the Middle Ages to the eighteenth century tried to equate musical intervals with signs from the zodiac, theories of the humours (fire, earth, water and air) the music of the celestial spheres, and so on. Even Isaac Newton dabbled in some of this. Music played on an electronic instrument in equal temperament should sound satisfactory in any key provided you only want to hear the tune and ignore any resonance that comes with a different pitch. If you are used to singing along to a familiar melody you will detect a large change in pitch because your voice is used subconsciously as a personal tuning fork. A piano may sound different in different keys because the hammers are more worn down or unevenly adjusted on different notes. But essentially in equal temperament there is no difference of mood between one key and another. Setting aside the matter of perfect pitch, musicians develop an awareness of pitch through experience and repetition. The brain analyses a spectrum of sound and compares it with a "catalogue" held in the memory. A string quartet in B flat played on instruments tuned a few cents above or below standard concert pitch would not sound noticeably different to most listeners, so long as the two pitches were not heard closely following one after the other. Tuning the instruments up or down as much as a semitone one will radically alter their natural string tension and resonance, changing the whole character of the sound. Similarly, players transposing to a natural or B natural alter the use of open strings and choice of fingering, thereby affecting the resonance in a different way.

Ian Gammie , St Albans Hertfordshire

Being myself a composer of symphonic music, I have had a particular interest in this very matter. For many years I assumed that it was a complete fallacy that particular keys had particular absolute qualities. After all, concert pitch these days is, I understand, something like a whole tone higher than in Mozart's day, so his celebrated G Minor symphony, for example, is nowadays played in something like the A minor of Mozart's day-yet we accept today's performance as a reasonable representation of Mozart's intentions. In fact the issue is considerably more complex than this. There are two main factors to be borne in mind. One is the actual pitch of the music, and the other is the sound-the timbre-of each instrument at a particular pitch. Let's briefly look at these. Absolute pitch: some of your readers may be surprised to learn that there is a strong evidence that many, if not most, people do have intrinsic perfect pitch. Through lack of training they haven't developed the ability to recognise pitches at a conscious level by name, but with appropriate training they could develop something of this ability. For at least most of us, particular absolute pitches do have their specific resonances in the mind, and therefore it is to be expected that even a semitone transposition of a musical work would cause at least a small difference in the effect of the work. Timbre: the sound and emotional effect of a musical scale is determined not only by the particular sequence of musical intervals at specific pitches, but also by the changes of timbre as the instrument moves from pitch to pitch. Also, string players have to change from one string to another at different points, and wind players similarly have to change between fundamental and harmonic or between different harmonics at particular points in their range. Here's a little experiment to try if you have the resources. Take a real orchestra and take a recording of them playing Mozart's G Minor Symphony tuned a tone lower than normal to approximate to the likely original concert pitch for that work. Also take a recording of them playing a version of the work transposed down a whole tone-that is, in the root key in F minor. Compare the recordings. You'd find that the two similarly-pitched performances had a different sound and at least some difference of emotional quality.
Philip Goddard , Exeter Devon

There may be some recent tests, but for a thorough examination of this topic see "The Science of Music" by Sir James Jeans, first published in 1937 but still available as a Dover paperback. Jean refutes the notion that, under equal temperament, there can be any emotional difference between keys, although he accepts that many musicians believe that there is. He puts it down to subjective imagination. He cites the old Lydian and Aeolian modes, which are equivalent to our major and minor scales. The Lydian (major) mode was associated with sorrow in Plato's time, and in the early church it was frowned upon as being too sensual-neither association matches our current perception. The issue is complicated by the repertoire. Before equal temperament became accepted, keyboards used mean tone tuning, and compositions were restricted to a few keys centred on C major, which was perfectly in tune. Remote keys, such as C sharp, were completely unplayable. This clearly had an influence on the way composers wrote music, even after equal temperament had ironed out the differences between keys. C major and its relatives for straightforward music, remote keys for introverted and melancholy music, such as Schubert's G flat Impromptu. Thus, we have an association which remains with us, even today. It has also been suggested that the relative length and width of the keys on a piano makes a difference to the force with which black and white notes can be played: C major is all white, and can be played with great noisy crashes that are very difficult on black notes. On stringed instruments, the open keys (G, D, A and E for a violin) have similar characteristics to C on a piano, given that it is easier to play a scale which includes several open strings than a scale where every note has to be fingered.
Christopher Lambton , Edinburgh

The Vibrating String
The basic principle underlying all western musical tuning systems has been ascribed to Pythagoras, who lived in the sixth century BC. There is no hard evidence for this, but whatever its precise origin, the system itself is the result of a brilliant piece of inductive logic, which impresses by its simplicity and "correctness". The system derives from the vibrations of a taut string, which inherently is capable of vibrating in a number of different ways. The simplest is where half a wavelength fills the string, but in principle the string can sustain any vibration involving a whole number of half waves. The possible combinations lie in the ratios: 1:2:3:4:5:6:7:8:9:10: .... etc. This progression simply records the number of half wavelengths in the string, but it is a simple matter to see that, for any given length and tension, it also represents the ratios of vibrational frequency of the string in each of the successive modes of vibration. This progression of frequencies is called the harmonic series.

The Discovery of Harmony
What Pythagoras is said to have discovered is that certain components of the harmonic series sound pleasant, or harmonious, when sounded together. This is true for any combination of the first six harmonics in the series: 1:2:3:4:5:6. The first, and obvious, implication of this progression is the repeated occurrence of a basic harmonious interval of 1:2, as shown in the ratios 1:2, 2:4 and 3:6. This interval is now called the "octave". . The next component, the seventh harmonic, is the first which sounds discordant in relation to any of the others. This will be familiar to players of the bugle as the horribly sharp high A, which is notoriously easy to hit by accident. If we seek harmony, we do best to stop at six.

Creation of a Scale
To create a more finely-divided musical scale from this series of numbers involved two distinct logical stages. The first of these was to recognise that the ratio of 1:2 is equivalent to both 2:4 and 3:6. By eliminating these duplicated ratios, the harmonious series was simplified to its inherent ratios: 2:4:5:6. Mathematically, this is simply the removal of redundant information; by very simple processes of integer arithmetic, any of the combinations in 1:2:3:4:5:6 can be obtained from 2:4:5:6. The second logical stage was to use this simplified series of ratios to subdivide the large interval of 1:2 into smaller intervals. In principle, this subdivision can be taken to any desired degree depending on the need for simplicity or expressiveness in the scale. A scale of only four notes is possible, but the results are rather unsubtle, as witness the rather obvious melodies written for unvalved brass instruments such as the bugle. By contrast, some oriental tuning systems have a large number of closely-spaced notes, allowing many more possible combinations and a much greater degree of expressiveness. In western music, the basic division has, since the very earliest times, been into a scale consisting of eight notes. After eight notes the scale repeats itself, hence the derivation of the word octave.

The Diatonic Scale
The subdivision between the notes of the western scale takes the form shown below: Succeeding notes are in ratios of 8:9, 9:10 or 15:16. Although not equal, the ratios of 8:9 and 9:10 are called tones, while the closer ratio of 15:16 is called a semitone. Because of the two types of interval, the term diatonic scale is used. The intervals run: tone: tone: semitone: tone: tone: tone: semitone.

The Sense of Key
Because of the asymmetric structure of the scale, it is very easy to spot, from hearing just a few notes, precisely where in the scale they lie. This gives a very powerful identity to the scale; its organisation points very clearly to the home note, or tonic, which in the scale shown above is C. We intuitively expect a musical statement to be resolved by a return to the tonic note; if this does not happen, an open-ended and incomplete impression is created.

Modal Scales
Medieval music often used modal scales, in which the need for sharps or flats was ignored when starting a scale on a note other than C. The basic diatonic pattern of tones and semitones is replaced by a different pattern for each mode, giving rise in some cases to eerie and expressive music. The modal scales can be heard easily by playing only the white notes on a piano, but starting and ending on a note other than C.

The Chromatic Scale

An obvious extension of the diatonic scale is to split the whole tones into semitones, so that, for example, the note C, increased in the ratio 16:15, becomes an intermediate note called C sharp (C#). The notes E and B obviously cannot have sharps, and so an enlarged scale of just 12 notes is produced. Because some of the harmonies in the enlarged scale are strange, and technically discordant, the term Chromatic Scale was adopted to describe the sometimes highly-coloured sound of the semitone scale. By an equivalent process, any note of the scale, except for C and F, can be flattened in the ratio 15:16 to produce its equivalent flat. (Symbol: b). A crucial point to note is that the frequency of a flat note is never the same as that of the equivalent sharp. Thus, for example, Eb and D# are different notes which sound at different pitches.

The Use of Different Keys

The main historical reason for the development of the chromatic scale is connected with a desire to change the pitch at which a particular piece of music is heard. The most obvious reason for such a key change is to match an instrument to the most comfortable range of a human voice, but, by the middle ages, key transitions were in widespread use, in their own right, as a means of introducing contrast between different passages of music. In order to retain the fundamental tone to semitone ordering of the diatonic scale, certain notes must be replaced by their sharp or flat equivalents if the scale is to start and end on any note other than C. This gives rise to the key signature, the pattern of sharp or flat symbols which appears at the opening of a score.

The Sound Quality of Different Keys

Because the interval of a tone may be either 8:9 or 9:10, the internal frequency relationships within a scale will depend on the key which is in use. For an example, the key of C starts with a ratio of 8:9, whereas the key of D starts with a ratio of 9:10. Worked out fully for these two keys we find the following frequency ratios: The internal differences between these two keys are fairly subtle, but in every key there is a different pattern, and for some, the differences are so great that the overall effect can be markedly discordant. Composers have always had views on the subjective emotional quality of different keys. Beethoven, for example, regarded the key of Eb as heroic in sound, and used it for both the Emperor Concerto and the Eroica Symphony, and also, in its equivalent minor mode, for his Fifth Symphony. As we shall see shortly, by the time of Beethoven, such views could not be sustained in terms of internal frequency intervals within individual keys, because the issue of tuning had reached such a critical state that an entirely new system of tuning had come into being.

The Equal Temperament Scale

Well before the start of the eighteenth century, the technical quality of musical instruments, and the virtuosity of their players had created a major crisis in the technicalities of tuning. At a fundamental level, composers and performers wanted to use harmonic effects and key progressions which, quite simply, sounded unacceptably discordant when used together. This was really the end for the Pythagorean tuning system, which could only provide perfect tuning for one key at a time. If a performer wished to change key, his instrument would, in theory, have to be retuned. Various solutions to this problem were sought, all involving the basic principle of compromise tuning; sharing out the errors in tuning throughout the whole chromatic scale in such a way that the widest use could be made of an instrument's capabilities. Many laudable attempts were made to retain the most fundamental harmonic progression of the major triad, the mathematically-precise 4:5:6 relationship of the notes C:E:G, but all these are now history; since the time of Bach, the principle of Equal Temperament has been in almost continuous and universal use. The equal temperament scale does the most radical and mathematically-precise job possible of dividing up the tuning errors between the notes. The mathematical principle is that the octave, with a frequency range of 1:2, is divided into twelve precisely equal geometric steps, to give the twelve semitones of the diatonic scale. Each note of the scale can be calculated from the previous note by multiplying its frequency by 21/12 (=1.0595).

Plus and Minus

The overall consequences of the equal temperament scale are a mixed bag. On the positive side, an instrument may be played in any key with no change in tonal relationships, and flats and sharps become truly equivalent (eg Ab = G#). On the negative side, every single note in the scale (except for the octaves) is out of tune to some extent, with the result that the intrinsically harmonious ratios of 4:5:6 are never heard exactly in modern performances. There are a few recorded examples of performances on keyboard instruments with Pythagorean tuning, with results which are said by reviewers to be a "revelation".

Additional Notes

Chromatic Scales. The table shows the tuning for each semitone in the scale of C, based on the modern standard pitch with A fixed at 440 Hz. Frequencies are in Hertz, Py = Pythagorean Tuning, Eq = Equal Temperament.

Nick Pillans , London

Mother's darlings

When Dad's a stunner his chicks get special treatment

FEMALE zebra finches give chicks fathered by their favourite mates a boost when they are still in the egg. The finding could be a headache for biologists, as this kind of trick makes it difficult to tell whether the father's genes or the mother's extra help allows offspring to thrive.

Several studies of birds have shown that females tend to go for highly ornamented males, and that when they do, their offspring have a better chance of survival. It is generally thought that this is because these males have superior genes.

However, testing this has been complicated by the fact that some mothers seem to invest more in raising chicks fathered by good males. Some experiments have controlled for this effect but evolutionary biologist Diego Gil of the University of Paris in Nanterre suspected that there may be an even bigger problem.

Gil and his colleagues at the University of St Andrews had a hunch that females also give chicks from favoured mates a helping hand by depositing more testosterone in the egg. Chicks in eggs with high levels of testosterone are usually the first to hatch, beg more for food and grow faster than the others.

The researchers randomly attached either red or green bands to the legs of a number of male zebra finches *(Taeniopygia guttata)*. Females find the lure of the red bands even more attractive than the male's traditional ornament its red beak. They then allowed six females to mate with the red males, and six to mate with the greens. The clutches of eggs produced by these liaisons were taken away for hormone analysis. The two groups of females were then swapped around and allowed to mate with males of the other colour.

The females deposited significantly more testosterone in all the eggs from the preferred red-banded males *(Science, vol 286, p 126)*. The researchers aren't sure how this happens, but it could be that the females' general levels of arousal increased their own hormone levels, which in turn affected the eggs.

This doesn't mean that there is no connection between ornaments and superior genes -but it does make testing the idea a lot harder "This is a remarkable study-it raises lots of new and exciting questions," says bird behaviour expert Tim Birkhead of the University of Sheffield. "That clearly you have to take these maternal effects into account is an important message for all those people looking at good genes." **Matt Walker** [New Scientist 9/10/1999]

The Call of the Wild

Humans may have to search high and low for traces of absolute pitch, but other animals flaunt the talent. Researchers have found that bats, wolves, gerbils and birds all sometimes use forms of absolute pitch to spot possible mates-or meats-amid nature's cacophony. Songbirds, in particular, put humans to shame, in a 1998 Study, psychologist Ron Weisman at Queen's University in Ontario, Canada, pitted 10 male zebra finches against 10 accomplished musicians. The birds had to decide whether to fly to a feeder that opened only when tones within four narrow frequency ranges were played, while the humans pushed a button to indicate whether a pitch was in one of the designated ranges-and won prize money for correct answers.

Towards the end of the experiment, Weisman says, the feathered participants identified pitch correctly 85 per cent of the time, while our species succeeded lust over half the time, "We didn't have the heart to tell these skilled musicians that their performance was abysmal compared to a bunch of birds," says Weisman.

But there's good reason for these creatures' virtuoso performances: zebra finches recognise members of their own species by the pitch range of their songs. "And it you've ever heard birds in a dawn chorus, you know how hard it is to distinguish one bird among the crowd," says Weisman.

Zebra finches can identity the absolute pitch of a mate's song up to 100 metres away, he says.

Songbirds and songwriters do have some things in common, though. Both birds and humans with absolute pitch can often switch to relative pitch as well, Weisman says. What's more, the birds hone their ear for pitch during youth, when they listen for the calls of family members and neighbours. There are some music lessons, Weisman notes, that really pay off.

Author

Kathryn S. Brown is a science writer based in Columbia, Missouri
For more information about absolute pitch, visit www.provide.net/~bfield/abs_pitch.html.
Levitin's work is described at http://cm.stanford.edu/~levitin/AP_casys.html, and details of the UCSF study and an opportunity to test your own pitch perception can be found at http://www.perfectpitch.org

---

MAIN INDEX									
REFERENCE GUIDE			TRANSCRIPTS				MIDI-GLOSSARY		
Chaos	Quantum	Logic	Cosmos	Conscious	Belief	Elect.	Art	Chem.	Maths

---

New Scientist 4 Dec 1999 **File Info:** Created *26/8/2003* Updated *20/8/2003* **Page Address:** http://members.fortunecity.com/templarser/rightnote.html