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Staying in tune

A BASIC ASPECT OF WESTERN MUSIC, WHICH WAS BELIEVED TO BE NATURAL AND INNATE IN HUMANS, HAS BEEN FOUND TO BE A CREATION OF CULTURAL TRAINING, WRITES **S ANANTHANARAYANAN**

he scale or pitch sequence of musical notes employed in most systems follows a simple, mathematical relationship. While the pitch of a note and its octave are separated by a factor of two, the intervals that fall in between are separated by approximately equal differences in pitch, which can be described by mathematical ratios of simple integers. The apparent structure and simplicity led to the idea that appreciation of forms of music could be something "wired in" and music in different parts of the world may share basic features.

Another feature that is common in western music is the choice of combinations of notes that can be sounded together to be pleasant and not jarring. There seems be a reason for such combinations, too. In the case of the first, third and the fifth steps of the scale, for example, which is one of groups that appear together in Western music, the ratio of frequencies is such that many of the overtones, or the octaves of the different notes, are of equal pitch and the overall sound is rich and well rounded. The use of such groups of notes, which are said to be consonant, is ubiquitous in Western music and it has been believed that comfort with these combinations is universal and must be shared by all peoples of the world.

Josh H McDermott, Alan F Schultz, Eduardo A Undurraga and Ricardo A Godoy from the Massachusetts Institute of Technology and Brandeis University, Massachusetts, Texas and San-

Consonance in Indian music

THE Maihar band that the legendary Allauddin Khan created in the village of Maihar in Madhya Pradesh to provide livelihood to the children orphaned by an epidemic, may be the only formal example of polyphony in the Indian classical tradition. Consonance, however, is very much part of Indian musical awareness — ready examples being the drone of the "tonic-fifth-octave", the "sa-pa-sa", which helps vocalists hold the pitch. The percussion instrument, the tabla, is also tuned so that the strokes are in consonance with I the keynote or other dominant tone of the vocalisation.

Synthe	tic chords	Sung chor	as S	ynthetic tones	Vocalisa	tions	Synthetic tones							
Like	Consonant Dissonant Consonant			armonic <mark>a I</mark> nharmoni	c 🔳 Laughs	Gasps	Smooth 📕 Roug							
Dislike		6600			h h h		hhh							
a b	c d e	a b c c	le a	b c d e	a D C	a e a								
fromNature (a=musi	cally trained An	iericans; b= untrai	ned Americans,	c= from Bolivian cap	ital; d= Bolivian	small town and e	e= Tsimane natives							
Steps of the s	cale													
1	1 2 3		4	5	6	7	8/1							
			 00	ctave or doubling	the frequence	cy								
The interval of the 'fifth'														
1/1 rati	9/8	5/4	4/3	3/2	5/3	15/8	2/1							
24/24	27/24	30/24	32/24	36/24	40/24	45/24	48/24							
C note na	D mes	E	F	G	А	В	С							
Sa	Re	Ga	Ma	Pa	Dha	Ni	Sa							
The free	quencies of	the notes of t	he scale go	up, not quite un	iformly, but	in simple ra	tios							

How overtones match when a consonant chord is played																				
1st	24			48		72		96		120	144		168		192		216	240		264
2nd		30			60		90			120	1	150		180		210		240		
3rd			36			72			108		144			180			216		252	
Matcl	h					1.5				1.3	1.5			3.5			1.5	1.3		

a remote tribe in the Amazon who had negligi- notes, which are in harmony with the main ble exposure to Western music to see if this was melody note and the accompaniment usually true. They report in the journal *Nature* that changes according to the rhythm to which the while the *Timane* people had a musical system of their own, they did not respond to musical sounds in the way persons in the Western world do.

tiago in Chile, studied the response of people of could be accompanied by notes, or groups of melody is set, as a "progression". The same melody could also be played at the same time in more than one sequence of pitch, with the notes of the different sequences, which are sounded together, being in harmony. The use of harmony and the simultaneous progress of different melodies, known as counterpoint, enrich Western orchestral music, which now has a vocabulary of musical representation of different moods and human emotions — the magnificent, pathos, valour, despair and so on. The idea of harmony and mood is basic to Western music and there are specific kinds of note groupings, called chords, which are recognised as "happy" (major chords) or "contemplative or gloomy" (minor chords).



dents of the USA, (b) residents of the city of La Paz, capital of Bolivia, (c) a rural town, San Borja, and (d) a native, horticulturalist-forager community, the Tsimane, in Santa Maria, a remote village in the Amazon rainforest.

A series of sounds, which are considered pleasant or unpleasant by conventional Western standards, was presented to the persons tested to see if they were sensitive and could identify the conventional classification, The sounds presented were (i) consonant chords, like the first, third and the fifth steps of the scale played together, or dissonant chords, which were combinations of the first and second step, or the first and the seventh step; (ii) the same note in different octaves, or a pair of notes slightly off harmony; (iii) rough tones, which were closely separated one that produce a rise and fall in volume; and (iv) to test for recognition of real moods, the sound of laughter and gasps.

Among the US residents there were two groups — one of persons who had musical training and the other of persons who had not. The three groups in Bolivia ranged from those that had considerable exposure to Western music to the isolated natives who had no exposure at all. The Tsimane natives, in fact, have a traditional music system based on scales, but their music never uses any group singing or two notes appearing at the same time, even in the form of an accompanying percussion. This group, hence, was clearly without any exposure to consonance or dissonance — and their recognition or preference to either of such sounds would be indicative of reasons other than practice or cultural training.

The results of the trials were that while the all the city and town groups showed clear preference for consonant or harmonic sounds, with the musically trained group showing the most marked preference, the Tsimane group was quite indifferent in all of the trials, except the one with the laugh and the gasps. They were just as sensitive as the other groups to prefer laughter, which is pleasant, to gasps, which suggest sorrow or pain and are abhorrent. But they were deaf to the qualities of consonance or harmonising of sounds, which form the bedrock of Western music. The findings reveal that musical appreciation is really not innate or biological but culturally regulated and results from socialisation. A formal study of the question has not been made so far, the authors of the paper say, and is also difficult as there are few communities whose musical sensibility is still unaffected by a culture that has labelled consonant sounds as beautiful. The study of the Tsimane people may have been just in time to show that there are other ways of hearing sounds than what we know of.

PLUS POINTS



Scientists might have found the closest ever candidate for

Second

earth

another earth that could support life, according to reports, but nobody will say whether it's true. The newfound planet orbits around a now wellinvestigated star close by Proxima Centauri that is similar to earth and could support life, it is claimed.

The researchers found the planet is expected to show up at the end of August even as one report said it will be the closest "second earth" ever found. The Proxima Centauri star is part of the Alpha Centauri system, which includes our solar system. "The still nameless planet is believed to be earth-like and orbits at a distance to Proxima Centauri that could allow it to have liquid water on its surface — an important requirement for the emergence of life," German newspaper Der Spiegel reported, but gave more details. A spokesperson for the European Southern Observatory has refused to comment on the report but said that he was aware of it.

The National Aeronautical and Space Administration revealed a second earth to much fanfare last year and the planet in the picture, called Kepler 452b, is just 60 per cent larger than earth and in many other ways. But since it is so far away — 1,400 light years — the chance of ever getting there or learning much more about it is limited. The new discovery is far, far nearer — just 4.24 light years away — but still too far away to actually visit with today's technology. This means we will be able to learn far



Melody and harmony

While melodies are created by arranging the notes in sequences, according to a metre, or periodic time pattern, an embellishment is the sounding of different notes at the same time. Any two notes, however, cannot be played or sung together and there are rules of which musical notes may be sounded together. That some pairs, or triads, or even more notes, played together are pleasing to the ear while others are not is the basis of much of Western music. These notes, or groups of notes, which sound well when played together are said to be consonant or in harmony.

This sounding of simultaneous but different notes, often in separate melodies, is known as polyphony and formed the basis of early church music and all of Western classical music. Thus, a melody created out of the notes of a scale

Is it universal?

Josh H McDermott and colleagues note in the paper that the belief that the sense of harmony is universal, with a biological basis that applies to all people, has not been tested in practice. They, hence, carried out trials to compare the preference for consonant sounds of (a) resi-

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NO MINOR PATHWAY TAPAN KUMAR MAITRA EXPLAINS HOW THE TCA CYCLE ALSO PLAYS A CENTRAL ROLE IN THE CATABOLISM OF FATS AND PROTEINS

 \mathbf{T} t is essential to understand the central role of the TCA cycle in all of aerobic energy metabolism. ■ Thus far, glucose has been regarded as the main substrate for cellular respiration. But while most summary reactions written for chemotrophic energy metabolism assume glucose as the starting compound,

we must also note the roles of alternative fuel molecules in cellular energy metabolism and the TCA cycle, especially fats and proteins. Far from being a minor pathway for the catabolism of a single sugar, the TCA cycle represents the main conduit of aerobic energy metabolism in a broad spectrum of organisms from microbes to higher plants and animals.

The role of fats in energy storage has been noted and it is observed that they are highly reduced compounds that liberate more energy per gram upon oxidation than do carbohydrates. For this reason, fats are an important long-term energy storage form for many organisms. Fat reserves are especially important in hibernating animals and migrating birds and also represent a common form in which energy and carbon are stored by plants in their seeds.

Most fat is stored as deposits of *triacylglycerols* (also called *triglycerides*), which are neutral triesters of *glycerol* and long-chain *fatty acids*. Catabolism of triacylglycerols begins with their hydrolysis to glycerol and free fatty acids. The glycerol is channeled into the glycolytic pathway by oxidative conversion to dihydroxy-acetone phosphate. The fatty acids are linked to coenzyme tively degraded by a sequential, stepwise process that involves the successive oxidation and removal of two-carbon units, generating acetyl CoA and the reduced coenzymes NADH and FADH₂. tial oxidative event in each successive cycle acids to the TCA cycle. occurs on the carbon atom in the ? position of the fatty acid. Thus, the fatty acids derived from fats, like the pyruvate derived from carbohydrates, are oxidatively converted into acetyl CoA, which is then further catabolised by the TCA cycle. Moreover, the enzymes of fatty acid oxidation are localised to the mitochondrion in many (though not all) eukaryotic cells, so the acetyl CoA derived from fats is usually generated and catabolised within the same cellular compartment. Proteins are not regarded primarily as energy sources because they have more fundamental roles in the cell — as enzymes, transport proteins, hormones and receptors, for example. But proteins can also catabolised to generate ATP if necessary, especially when carbohydrates and lipid stores are depleted or not available. In animals, protein catabolism is prominent under conditions of fasting or starvation, or when the dietary intake of proteins exceeds the need for amino acids. In plants, catabolism of proteins to free amino acids provides building blocks for protein synthesis during the germination of protein-storing seeds. In addition, all cells eventually undergo a turnover of proteins and protein-containing structures, and the amino acids to which the proteins are degraded can either be recycled into proteins or

degraded oxidatively to yield energy.

Protein catabolism begins with hydrolysis of the peptide bonds that link amino acids together in the polypeptide chain. The process is called *proteolysis*, and the enzymes responsible for this are called pro*teases.* The products of proteolytic digestion are small



The math behind the speed IT'S QUESTIONABLE WHETHER THE 100 METRES ALWAYS PRODUCES THE FASTEST PERFORMANCE, WRITES **CHRISTIAN YATES**

270

answer is, in fact, Justin Gatlin. In 2011. he ran the 100 metres in 9.45 seconds, the fastest time a human has ever run that distance, smashing Bolt's best time by a massive 0.13 seconds. At the time, the controversial US athlete — twice banned from competing for drug-related offences — was being pushed along the track by a huge 20 metre-per-second tailwind (the limit for a time to be ratified as a record is +two minutes/second). The wind was generated by a number of giant fans as part of a Japanese game show, so the "record" didn't count. Nevertheless, no one has ever been recorded to run faster from a stationary start on the flat – although some sub-world record times have also been clocked for people running downhill.

When Roger Banister looked out the window on the morning of 6 May 1954, for example, he almost decided to postpone his attempt to break the four-minute mile record because it was too windy. Just before the event, however, the winds dropped enough for him to want to take part and the rest is history. He knew what mathematics could prove: that if you have to do at least one lap of the track, then wind, no matter how light, will always slow you down. Consider a wind blowing up the home not having to react and accelerate up to track. When Mo Farah runs with the wind, his speed is increased by a set amount, but when he runs against it on the back straight the wind decreases his speed by the same amount. It seems reasonable that these two effects might balance each other out giving Farah the same lap time as if there were no wind at all. Strangely, however, it doesn't work out that way.

W ho's the fastest man on earth? Usain the men's. The team concluded that if trends continued as they have over the last 90 years, women could be dominating the 100 metres by 2156.

However, sports scientists have been critical of the findings and have suggested that increased participation and training opportunities for women over the same time period had led to the artificially rapid reduction in their 100 metre times in comparison to the men's. They argue that now men and women are on a roughly level playing field the decrease in women's 100 metre times will begin to slow to a rate comparable with that of the men. Critics also cite fundamental difference in men's and women's physiology, including oxygen carrying capacity and body fat levels, which suggest that the "fastest person on earth" will never be a woman.

In fact, although billed as the race for the fastest person on earth, it's questionable whether the 100 metres always produces the fastest performance. When Bolt set two new world records for the 100 metres and 200 metres at the 2008 Bejing Olympics, his 200 metres took him 19.30 seconds, less than twice the time of his 9.69 second 100 metres. This means that on average, he was running faster in the longer event.

Part of this increase, however, is due to

more about the planet than we could about further away ones.

ANDREW GRIFFIN/THE INDEPENDENT

Roach milk

Milk secreted by a cockroach species to feed its young is the base for a potent nutritional supplement being developed by Indian and international scientists. "While cockroaches are oviparous (egglaying animals), the Diploptera *punctata* species alone is viviparous



(animals that give birth to young) and nourishes its offspring with a milk protein," says Sanchari Banerjee, a postdoctoral fellow at the Institute for Stem Cell Biology and Regenerative Medicine, Bangalore, where work is underway to develop the food supplement.

Banerjee and fellow researchers found that the milk, which the mother cockroach secretes through the brood sac, gets converted into concentrated protein crystals that are stored in the gut of the embryos. They describe their work in a paper published late July in *IUCrJ*. "Now that we know the chemical constituents of roach milk, the challenge is to produce the milk in yeast using biotechnology techniques," says Nitish Sathyanarayanan. Supported by India's department of biotechnology, the team has members drawn from diverse institutions, such as the Carver College of Medicine, University of Iowa; Department of Cell and Systems Biology, University of Toronto; and Experimental Division, Synchrotron Soleil, Gif-sur-Yvette, France.

Biophysical and X-ray crystallographic studies of the crystals show that they are composed of a mix of proteins, sugars and fatty acids that make a complete food for the roach brood.

Tracking whales

Humpback whales skirt the ocean floor to forage for their meals but low frequency sounds from ships can slow their descents, making it potentially

A to form fatty acyl CoAs, which are then oxida- Interconversion of several amino acids and their cognate keto acids in the TCA cycle. The amino acids (a), alanine aspartate (b) and glutamate (c) can be reversibly converted into the corresponding a-keto acids: pyruvate, oxaloacetate, and a-ketoglutarate, respectively. Each of these keto acids is an intermediate in the TCA cycle, a portion of which is shown to provide the metabolic context for these reactions. In each case, the amino group is This sequential process of fatty acid catabolism shown in blue and the keto group is shown in yellow. These reactions are to acetyl CoA is called *? oxidation* because the ini- readily reversible and perform the catabolic function of converting amino

> peptides and free amino acids. Further digestion of peptides is catalysed by peptidases, which either hydrolyse internal peptide bonds (endopeptidases) or remove successive amino acids from the end of the peptide (exopeptidases).

> Free amino acids, whether ingested as such or obtained by the digestion of proteins, can be catabolised for energy. Generally, these alternative substrates are converted to intermediates of mainstream catabolism in as few steps as possible. In spite of their number and chemical diversity, all these pathways eventually lead to a few key intermediates in the TCA cycle, notably acetyl CoA, a-ketoglutarate, oxaloacetate, fumarate and succinyl CoA.

> Of the 20 amino acids found in proteins, three give rise to TCA cycle intermediates or precursors directly. These are the amino acids alanine, aspartate and glutamate, which can be converted to pyruvate, oxaloacetate and a-ketoglutarate, respectively. All the other amino acids require more complicated pathways, often with many intermediates.

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The reason, in essence. is that because you run faster down the home straight, you derive the

benefit of being pushed by the wind for only a short time. But when you run down the back straight, you spend longer going slower, fighting against the wind.

So wind and other adverse weather conditions can act as a leveller, adding to the uncertainty about the results of individual races. But whatever the weather, can we be confident that the world's fastest sprinter will always be a man? Well, perhaps not. Researchers from the University of Oxford found that, although 100 metres' times for both men and women had been decreasing linearly over the years, the women's time was decreasing at a much faster rate than

straight of a standard 400-metre athletics speed in the second 100 metres of the 200

metre race. Based on average speed over the whole race, the title of "fastest person on earth" has switched back and forth between 100 and 200 metre runners since the records began.

This effect is even more exaggerated in the 4x100-metre relay in which all but one of the runners begins their 100-metre stretch from a running start. In the last leg, the "anchor"

doesn't even have to worry about passing on the baton at the other end so can achieve some incredibly quick times. Several subnine second times have been recorded in this leg of the race, including Bolt's electronically-timed 8.65 seconds in 2014.

Despite this, the fast human footspeed was recorded between 60 and 80 metres in Bolt's world record 9.58-second 100 metres in Berlin. He was clocked at 44.64 kmph. So despite Gatlin's "record", the official "fastest man on earth" title still rests with Bolt — at least for now.

THE INDEPENDENT



more difficult to feed. according to a study published in *Biology* Letters. Whales have likely been enduring sound

pollution at the study site – the Stellwagen Bank National Marine Sanctuary between Massachusetts's Cape Cod and Cape Ann — for decades, according to study co-author David Wiley of the US National Oceanic and Atmospheric Administration. Now, the results of his team's study sounds "another warning that we do need to be very concerned about noise in the oceans because we don't know the impacts". The team of UK and US scientists used

archival tagging to track the behaviour and acoustic environment of 10 humpback whales from 2006 to 2009 and, in addition to finding that the animals descended more slowly when ships passed, the team also showed that the whales performed fewer side rolls — a technique they use to stir up sand lace, a fish found near the ocean floor.

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