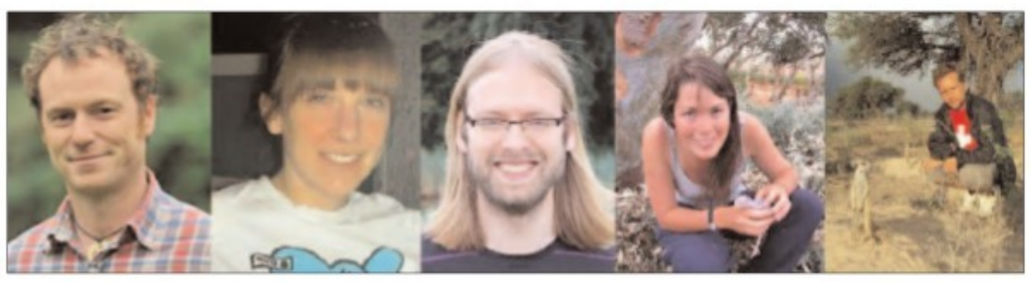
Word games in birdsong

FEATURES OF HUMAN SPEECH HAVE BEEN DETECTED IN THE CHATTER OF A BOISTEROUS AUSTRALIAN BIRD, WRITES **S ANANTHANARAYANAN**

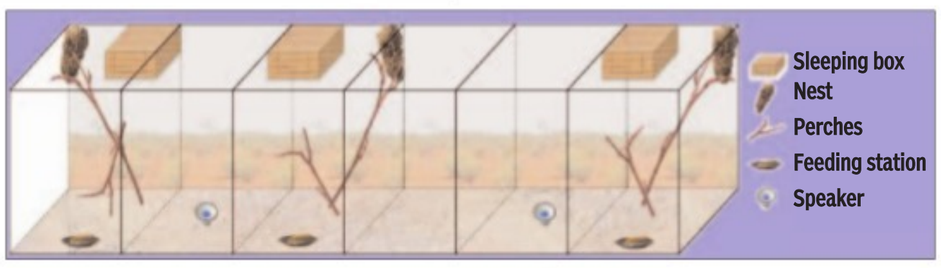
That birdsong and some bird calls have a structure that conveys meaning has been demonstrated in a number of studies. It has been shown that combinations of tones, in patterns according to different rules, a sort of grammar, can be distinguished. But there is no evidence of whether bird calls contain units of just a few tones in a specific order to form what may be considered "words" with individual meaning. If there are such units, they may be the rudiments from which more complex communication, as we see in humans, could have evolved.



Andrew F Russel, Sabrina Engesser, James L Savage, Jodie MS Crane and Simon W Townsend.

Sabrina Engesser, Jodie MS Crane, James L Savage, Andrew F Russell and Simon W Townsend of the Universities of Zurich, Sheffield, Cambridge, Exter and New South Wales describe in the journal *PLOS Biology* their finding that *Pomatostomus ruficeps*, the chestnut-crowned babbler, a bird found in the arid southeast of Australia, uses a simple pair of sounds to convey specific meaning when sounded one way, and another when sounded differently. "This is the first time that the capacity to generate new meaning from rearranging meaningless elements has been shown to exist outside of humans," says Dr Townsend from the University of Zurich, one of the authors of the paper.

That sequences of a pair of tones that follow a rule of formation can be learnt and distinguished by the European starling has been shown by studies of *habituation* to a pattern when heard repeatedly. It has even been shown that it is a particular part of the brain, the *frontal nidopallium*, that is affected when a familiar pattern is changed. Injury to this portion of the brain has been found to affect song recognition in canaries and the zebra finch, which is akin to injury to some parts of the human brain leading to selective language impairment.



Specific patterns of whistles of the male white-throated sparrow have been shown to appear at breeding time, both as a courting call addressed to females as well as a warning or a challenge to males. These sounds are found to affect the female sparrow in parts of the brain that are associated with reward, at a time when she is ready to mate, and the response has been found to be similar to human response to music when the music is appreciated. But these are observations that birdsong is positively a form of communication, rather than evidence of "speech-like" organisation that we find in humans.

The *PLOS Biology* paper notes that human speech is characterised by just a few sounds that have no meaning by themselves, being arranged in different ways to create the dictionary of words with specific meaning. They cite the example of the three meaningless sound elements, which are called *phonemes*, in the word "cat". These can be rearranged as "act" or "tack" and the difference is recognised as conveying different meaning, and the prefix "c" to the phoneme "at" can be seen as creating meaning not suspected before. Varying the phoneme pattern to create words and then the rules to combine different words leads to the versatility of human language, but there is little known of how the capacity may have evolved, the paper notes.

Animal studies so far have not shown instances of the use of phoneme structure to convey meaning, they observe. There is evidence of a basic layer of syntax in the communication of non-human primates. For instance, certain monkeys produce two calls that announce specific predators, and the meaning of the calls are changed to a general alarm if a particular suffix is added. But as the calls themselves have meaning, and so also the suffix can be considered to have, this is not a case of "phoneme" structure, the authors note. Even in the case of behaviour changes in birds in response to variation in birdsong, the variations are of a higher order structure and there is still no evidence of rearranging the elements of birdsong leading to contextual change in meaning.

Chestnut breasted warbler

The *PLOS Biology* authors now report an instance of just this in the repertoire of the chestnut crowned babbler, a highly social and cooperatively breeding bird. In earlier studies, it was observed to have at least 15 context-specific calls. Out of this collection, the team has taken up a specific pair that share constituent elements — a double element call used during flight and a three-element call used when encouraging the newly hatched young to feed. The elements of the flight call are denoted as F1 and F2 and the elements of the call at feed time, or the prompt call, as P1, P2 and P3.

An important feature of the five elements involved was that each was individually meaningless and represented no context. This said, frequency and volume analysis of two calls established that they were equivalent to the use of two elements only — either as AB in the flight call, or BAB in the prompt call.

Next was analysis of the context in which the calls were sounded. It was seen that flight calls arose in 274 out of 450 natural flights and in 58 out of 90 capture-induced flights. But there were no prompt calls. Even in flights to and from nests, 62 per cent of the flights had flight calls and 70 per cent of events with nestlings had prompt calls, and prompt calls during flights or flight calls in nestling provisioning were rare. This establishes that the two-element AB call was specifically for maintaining group cohesion during flight and the three-element, BAB call was specifically for help in food transfer to offspring birds in the nest.

Response to variations of the elements in the two- and three-element calls were then investigated with the help of playback of recorded bird calls while the birds were placed in compartments with perches, food, a window and a nest. The calls sounded were two natural calls, two calls where equivalent elements F1, F2, P2 and P3 were switched and two calls with P1 alone or a three-element call with an external element as the first, in place of P1. If the bird recognised the call as a flight call, it would look out of the window, but if it were a prompt call, it may look towards the nest. The source of sound was in the neighbouring compartment and the bird had to look away from the sound source to look out of the compartment or in the opposite direction to look at the nest.

The results were that the birds responded to natural calls just as they did in field trials, which confirms that the two-element and three-element calls are distinct. Again, when the equivalent elements in the calls were switched, to test for any accoustic quality of the equivalent elements being responsible for the differences in response, it was found that the response remained essentially the same. The difference in the response to the two-element call and the three-element call was, hence, seen to arise only because of the element P1 in the first position in the three-element call. The third kind of trial was with the element P1 alone and then a three-element call with P1, which was in first position replaced by "C", an external element derived from general chatter of the bird.

This third trial was found to increase the "looking out" activity and general movement, which could be attributed to a "different sound", but there was no increase in the nestward looks, which were otherwise stimulated by three-element prompt calls.

The P1 element thus appears to be the differentiator, like the "c" in "cat", and this becomes an instance, the first, of an animal using phoneme-like structure to differentiate meaning. "To our knowledge, this is the first demonstration that animals have the basic capacity to use phoneme-like contrasts to derive qualitatively new meaning…" the authors say. The discovery that this can happen in the animal world is significant in understanding the steps through which complex speech as in humans may have evolved. The authors says that "for vocally constrained, highly social species such as chestnut-crowned babblers, evolving new meaning by rearranging existing sounds offers a faster route to increasing communicative output than evolving new sounds", which may be the reason that this is the method that allows humans to communicate almost without limit but with an economical font of phonemes to play around with.

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Game-changer

One question that arises is why there were no trials conducted with other elements, like F1, F2, P2 or P3 in the first position in the three-element call. Andrew Russel responded to a query, "The first thing to point is out is that, strictly, this is not like 'cat' and 'at', but more like 'tat' and 'at'. This changes the game a bit because there are now less options to try (ie, 'tat' or 'att' or 'tta' are the only possibilities). Additionally, while 'att' and 'tta' are options, the birds do not use these combinations."

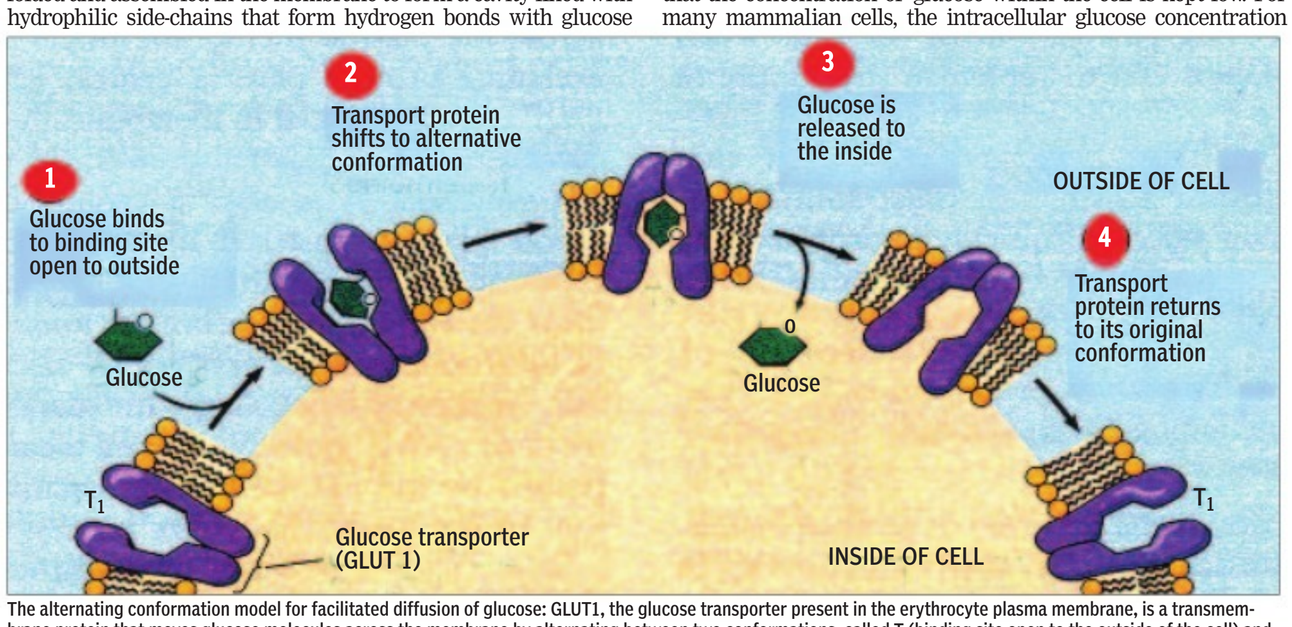
The calls used hence reduce to only AB and BAB, the initial "B" in the second call being the differentiator.

TRANSPORTERS IN TISSUES

TAPAN KUMAR MAITRA EXPLAINS THE MECHANISM BY WHICH GLUCOSE IS CARRIED OVER A PLASMA MEMBRANE

The movement of glucose into an erythrocyte is an example of facilitated diffusion mediated by a uniport carrier protein. The concentration of glucose in blood plasma is usually in the range of 65-90 mg/100 mL or about 3.6-5.0 mM. The erythrocyte (or almost any other cell in contact with the blood, for that matter) is capable of glucose uptake by facilitated diffusion because of its low intracellular glucose concentration and the presence in its plasma membrane of a glucose carrier protein or glucose transporter, abbreviated as GLUT. The GLUT of erythrocytes is called GLUT1 to distinguish it from related GLUTs in other mammalian tissues. GLUT1 allows glucose to enter the cell about 50,000 times faster than it would by free diffusion through a lipid bi-layer.

GLUT1-mediated uptake of glucose displays all of the classic features of facilitated diffusion — it is specific for glucose (and a few related sugars, such as galactose and man-nose) — exhibits saturation kinetics and is susceptible to competitive inhibition by related monosaccharides. GLUT1 is an integral membrane protein with 12 hydrophobic trans-membrane segments. These are presumably folded and assembled in the membrane to form a cavity lined with hydrophilic side-chains that form hydrogen bonds with glucose molecules as they move through it.



The alternating conformation model for facilitated diffusion of glucose: GLUT1, the glucose transporter present in the erythrocyte plasma membrane, is a transmembrane protein that moves glucose molecules across the membrane by alternating between two conformations, called T (binding site open to the outside of the cell) and T2 (binding site open to the inside of the cell). The transport process is shown here in four steps, arranged around the periphery of a cell. CD, With GLUT1 in its T (conformation, a molecule of D-glucose collides with and binds to the binding site on the protein. With glucose bound, the transporter shifts to its T2 conformation. This allows release of glucose to the interior of the cell, after which (4) GLUT1 returns to its original (T) conformation, ready for a further transport cycle.

GLUT1 is thought to transport glucose by an alternating conformation mechanism. The two conformational states are called T_1, which has the binding site for glucose open to the outside of the cell, and T_2, with the site open to the interior of the cell. The process begins when a molecule of D-glucose collides with and binds to a GLUT1 molecule that is in its T_1 conformation. With glucose bound, GLUT1 now shifts to its T_2, conformation. The conformational change allows the release of the glucose molecule to the interior of the cell, after which the GLUT1 molecule returns to its original conformation, with the binding site again facing outwards.

The process is readily reversible because carrier proteins function equally well in either direction. A carrier protein is really a gate in an otherwise impenetrable wall, and, like most gates, it facilitates traffic in either direction. Individual solute molecules may be transported either inward or outward, with the net direction of solute movement determined by the relative concentrations of the solute on the two sides of the membrane. If the concentration is higher outside, net flow will be inward; consequently, if the higher concentration occurs inside, net flow will be outward.

GLUT1 is just one of several glucose transporters in mammals. Each of these proteins is encoded by a separate gene and each has physical and kinetic characteristics that suit it especially for the specific tissues in which it is found. For example, GLUT2, the glucose transporter present in liver cells, has kinetic properties that adapt it well to its role in transporting glucose out of the cells when liver glycogen is broken down to replenish the supply of glucose in the blood.

The low intracellular glucose concentration that makes facilitated diffusion possible for most animal cells exists because incoming glucose is quickly phosphorylated to glucose-6-phosphate by the enzyme hexokinase, with ATP as the phosphate donor and energy source. This hexokinase reaction is the first step in glucose metabolism.

The low K_m of hexokinase for glucose (1.5 mM) and the highly exergonic nature of the reaction ($\Delta G^{0'}$ = - 4.0 kcal/mol) ensures that the concentration of glucose within the cell is kept low. For many mammalian cells, the intracellular glucose concentration ranges from 0.5 to 1.0 mM, about 15-20 per cent of the glucose level in the blood plasma outside the cell.

The phosphorylation of glucose also has the effect of locking glucose in the cell, because the plasma membrane of the erythrocyte does not have a transport protein for glucose-6-phosphate. (GLUT1, like most sugar transporters, does not recognise the phosphorylated form of the sugar.) This is, in fact, a general strategy for retaining molecules within the cell because most do not have membrane proteins capable of transporting phosphorylated compounds.

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Learning from Iron Man

SCIENTISTS SAY THE SUPERHERO'S AUGMENTED REALITY TECHNOLOGY COULD HELP SURGEONS AND FIREFIGHTERS. **STEVE CONNOR** REPORTS

Scientists have developed a method of projecting 3D holographic images into the field of view of an observer in an "augmented reality" breakthrough that could one day allow the likes of surgeons and firefighters to benefit from seeing the world through technology similar to that used by comic-book superhero Iron Man.

Robert Downey Jr in *Iron Man 3*. The superhero has data sent to his field of vision.

The researchers said it would be possible to use the holographic projections to provide extra information on objects in a person's visual field in real time in order to supplement their normal sense of vision using augmented-reality headsets — just like Iron Man's suit.

Details of the research will be released at summer science exhibition at the Royal Society later this week, which highlights the best of British scientific research and technical innovation — from the latest studies into the origins of life to robots with human-like hearing.

Augmented-reality headsets rely on a British device similar to a microscopic slide, which converts light from a computer or camera into a hologram that can be displayed in front of a person's eye and focused within their field of vision. "This optical technology is a game-changer for the development of augmented-reality devices. The applications for devices that allow people to view the world around them overlaid with data relevant to what they are seeing are endless," said Simon Hall, the lead scientist in adaptive optics at the National Physical Laboratory.

"There are many things you can do with augmented reality that can assist people in various professions, for example a firefighter trying to get an infra red view of a smoke-filled room; or you may think of the surgeon wanting to get more information about the operation that he's doing from a colleague across the Atlantic — or simply helping the blind to see," he said.

"We've all seen Tony Stark's view of the world when he wears his Iron Man suit — information about his world projected in his line of sight. Now we'll be able to experience it for ourselves. We'll be working with the developers of augmented-reality devices on a wide range of applications," Dr Hall added.

Other scientists displaying at the summer science exhibition have worked out a way of giving robots super-human hearing using a microphone that can zoom in on conversations within a noisy room. Patrick Naylor of Imperial College said the technology would allow machines to understand human conversations in noisy places, by focusing on individual voices.

"At the moment, robots, phones and other devices using speech recognition don't work well when you're not close to the microphone or (not) in a quiet space because there's just too much noise," he said.

THE INDEPENDENT

PLUS POINTS

Lucrative discovery

A tiny settlement in the sparsely-populated Northern Territory of Australia has been the subject of scientific attention after it was discovered that a nearby flood plain was home to an infestation of 25,000 tarantulas from a newly-discovered species.

However, rather than this unsettling news making sure that no one would ever visit the town again, a leading Australian arachnologist believes this could be good news for the remote community of Maningrada, which is over 300 miles from Darwin, the nearest city. Dr Robert Raven, a senior curator at the Queensland Museum, believes the venom of the spiders, which is strong enough to induce vomiting in humans, could be used for medical research purposes. Speaking to the *Sydney Morning Herald*, he said that "pharmaceutical applications could apply across a broad spectrum"

The spider, commonly called the diving tarantula due to its worrying ability to survive underwater by creating air bubbles, was only discovered in 2006 and its full potential as a medical resource has not yet been realised. The uniquely high concentration of spiders in Maningrada means it would make the business of finding the spiders and extracting their venom much easier.

Dr Raven said that the normal colony size was only around 200-300 spiders — around 100 times smaller than the size of the newly-discovered cluster. The sheer size of the Maningrada group could be very attractive to biologists and medical researchers trying to find out more about the under-researched creatures. He hoped the attractiveness of the region to researchers could work in favour of the small community, mostly made up of Aboriginal people. "This is a resource for the community in a number of ways... and this could flow back into the community eventually to help them manage the parks better."

DOUG BOLTON/THE INDEPENDENT

Morphine missing link

The recent identification of a poppy plant gene has brought researchers one step closer to making morphine in the lab rather than in fields. The protein the gene codes for, called STORR, was described on 25 June in *Science* and represents the last cog in the enzymatic machinery required to engineer yeast to produce morphine.

"The publication of this gene provides the missing link for the production of morphine in yeast — there's no doubt about it," study co-author Ian Graham, a geneticist at the Center for Novel Agricultural Products at the University of York, told the *Los Angeles Times*. "I think it's only a matter of time before there is a proof-of-concept demonstration in yeast that this can happen."

Researchers at the University of York and GlaxoSmithKline in Australia identified STORR by screening randomly-generated mutant poppy plants for their ability to make morphine. Plants with mutations in the gene encoding STORR were unable to make the opioid since, as the researchers discovered, STORR performs a key step in morphine biosynthesis by isomerising a morphine precursor called reticuline. The team also reported that STORR was a fusion product of two genes encoding an oxidase and a reductase enzyme.

"Plants produce an amazing array

of natural chemicals," Graham said. "The discovery of this STORR gene fusion provides us with new insight into how poppy plants have evolved to produce the most effective painkillers known to man."

But the discovery is also adding to concerns that it may soon be possible to produce "home-brewed" heroin. "You can see how quickly the technical challenges are being overcome, even faster than we anticipated," Tania Bubela, a researcher at the University of Alberta School of Public Health who was not involved with the study, said. "It speaks to the fact that policymakers need to get ahead of the technology."

AMANDA B KEENER/THE SCIENTIST