called locked-in syndrome. Consciousness might be absent in sleepwalking. Thus, coupling it to behaviour is misleading.

Nor is it straightforward to link consciousness to parts of the brain. One of Gazzaniga's earliest findings was that disconnecting the left and right hemispheres produced two separate conscious systems; only one, usually supported by the left brain, was able to express itself in language. It had been assumed that consciousness co-evolved with the cerebral cortex, supporting 'higher' functions such as language and reasoning. But referring to the work of neuroscientist Björn Merker, Gazzaniga makes the case that consciousness might not be necessarily — or exclusively — locked into cortical and linguistic processes. In some children born with a seriously compromised forebrain, the damaged tissue gets replaced by fluid (hydranencephaly). They grow up lacking language, but still express feelings and have subjective experiences. According to Gazzaniga, consciousness might actually originate in the evolutionarily older midbrain, with the cortex providing "a collection of extensions (apps!) to enhance conscious experiences".

In an engaging discussion of the brain's architecture, he offers a mundane simile for consciousness. The brain should be thought of as a multitude of modules, each specialized for a single task, such as recognizing patterns or monitoring rhythm in music. The end products of these modules rise to the surface and burst like "bubbles in a boiling pot of water", each a fleeting part of our awareness. Our subjective sense of continuity, described by pioneering psychologist William James as "stream of consciousness", might be illusion: we merely experience the rapid succession of elements as a smooth movement, like the frames of a film. The metaphor of the bubbles seems first and foremost an invitation to generate a testable theory, and Gazzaniga's observations will almost certainly provide much of the test material.

Gazzaniga ends by reflecting that the ultimate explanation for how mind emerges from meat might not prove "warm and cuddly". Instead, it might vie with quantum mechanics for sheer counter-intuitive weirdness, hovering "way beyond our intuitions and imaginations". Once again we seem to hear what Burman heard, 370 years ago: a sigh of resignation, as Descartes indicated that it might all be better left to the theologians. ■

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Tom Lehrer performing in San Francisco, California, in 1965.

MATHEMATICS

Tom Lehrer at 90

Andrew Robinson looks back at the scientific high notes in the mathematician and satirist's inimitable oeuvre.

In 1959, the mathematician and satirist Tom Lehrer — who turns 90 this month — performed what he characteristically called a "completely pointless" scientific song at Harvard University in Cambridge, Massachusetts. (He was a PhD student there at the time.) 'The Elements', now one of his most cherished works, sets the names of all the chemical elements then known to the tune of the 'Major-General's Song' from *The Pirates of Penzance*, the comic opera by W. S. Gilbert and Arthur Sullivan. Lehrer's heroically precise, rapid-fire enunciation of 102 elements (reordered to allow flawless end-rhymes), ends with the much-quoted crack, "These are the only ones of which the news has come to Harvard/And ▶

there may be many others but they haven't been *discarvard*."

In the 1960s, Lehrer followed up with more than a dozen astringent, cynical and often pointedly political songs, such as 'So Long, Mom, I'm Off to Drop the Bomb (A Song for World War III)'. As *The New York Times* had it, "Mr. Lehrer's muse [is] not fettered by such inhibiting factors as taste." (Lehrer reprinted the quote in his album liner notes.) In the fraught geopolitics and paranoia of the cold war, however, Lehrer's social criticism touched a chord with many in the United States. Fans might, however, have been surprised to learn that he had crunched numbers for the National Security Agency as an army draftee in the mid-1950s.

Much of Lehrer's oeuvre — some 50 songs (or 37, by his own ruthless reckoning) composed over nearly three decades — played with tensions at the nexus of science and society. His biggest hit, *That Was The Year That Was*, covered a gamut of them. This 1965 album gathered together songs Lehrer had written for *That Was The Week That Was*, the US satirical television show spawned by the BBC original. 'Who's Next?' exposes the dangers of nuclear proliferation. 'Pollution' highlights environmental crises building at the time, such as undrinkable water and unbreathable air.

The rousing ballad 'Wernher von Braun' undermines the former Nazi — who designed the V-2 ballistic missile in the Second World War and later became a key engineer in the US Apollo space programme. In Lehrer's view, it was acceptable for NASA to hire von Braun, but making him into an American hero was grotesque. "'Once the rockets are up, who cares where they come down?'/'That's not my department,' says Wernher von Braun" — lines that still resonate in today's big-tech ethical jungle. 'New Math', meanwhile, skewers the education system through the lens of a misfired revolution in mathematics, with its telling refrain: "It's so simple, so very simple, that only a child can do it" (A. Bellos *Nature* **516,** 34–35; 2014).

LYRICAL PRECISION

Lehrer — who grew up on New York City's Upper East Side — certainly sees a connection between his mathematical training, which began at Harvard at the prodigiously young age of 14, and his compositions. He was drawn to songwriting in his teens; after failing to respond to classical-music training, he switched to the study of popular music. In an interview in 2000, he summed up the fields' dual impact. "The logical mind, the precision, is the same that's involved in math as in lyrics," he said. "It's like a puzzle, to write a song."

The cover of Tom Lehrer's debut album, released in 1953.

LEHRER RECORDS

Lehrer agrees with mathematician Stanislaw Ulam (one of the builders of the atomic bomb) that rhyming "forces novel associations … and becomes a sort of automatic mechanism of originality". As he told me in 2008: "If 'von Braun' didn't happen to rhyme with 'down' (and a few other words), the most quoted couplet in the song would not exist, and in all probability the song itself would not have been written."

"The logical mind, the precision, is the same in math as in lyrics."

His musical career began at university, with the spoof sports song 'Fight Fiercely, Harvard'. In the early 1950s, Lehrer put on a satirical show in the physics department, *The Physical Revue* (a pun on the name of the US journal then named *Physical Review*). With co-performers including Norman Ramsey (later a Nobel laureate in physics) and Lewis Branscomb (who would become a presidential science-policy advisor), he performed ditties such as 'Relativity', 'Fugue for Scientists' and 'The Slide Rule Song'. It was a training ground for later triumphs.

He began recording in 1953. Although US radio stations refused to play such 'controversial' material, his fame spread through word of mouth. In Britain, the royal approval of unexpected fan Princess Margaret and the support of the BBC significantly raised Lehrer's profile, and he considered abandoning academia. But in 1960, bored by touring, he returned to Harvard, aiming to complete a long-standing mathematics PhD on modes in statistics. Soon, however, he concluded he had nothing original to contribute academically. As he notoriously wrote in 'Lobachevsky', a song named after a nineteenth-century Russian mathematician: "Plagiarize!/Let no one else's work evade your eyes!/… So don't shade your eyes,/but plagiarize, plagiarize, plagiarize/— only be sure always to call it, please, research." Lehrer dropped his doctorate and began to teach mathematics — at the Massachusetts Institute of Technology in Cambridge in 1962 and, from 1972 until his retirement in 2001, at the University of California, Santa Cruz (along with a class in musical theatre).

He also largely gave up songwriting and public performing in the early 1970s. Following the award of the Nobel Peace Prize to then-US Secretary of State Henry Kissinger in 1973, Lehrer commented: "Political satire became obsolete." And in 2002 he remarked, still less optimistically: "Things I once thought were funny are scary now. I often feel like a resident of Pompeii who has been asked for some humorous comments on lava." About the political earthquakes triggered by US President Donald Trump, Lehrer has been silent.

As for his songs, their vigour, concision, melodic variety and humour never stale. Although Lehrer is absurdly omitted from the *Encyclopaedia Britannica* (unlike his friend, the lyricist and composer Stephen Sondheim), his scathing creations remain one of the most original — not to mention mathematically elegant — bodies of artistic work to come out of the United States in the twentieth century. ■

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CORRECTION

The exhibition review 'Fake Views' (*Nature* **555,** 442; 2018) erroneously described the artist Ryuta Nakajima as a woman; he is a man.