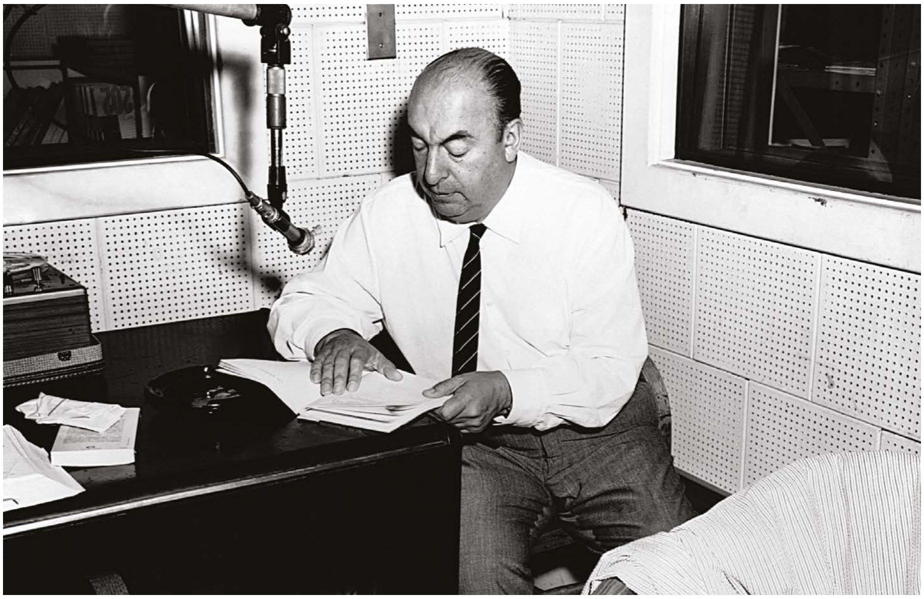


Pablo Neruda reads some of his poetry during a radio interview.

WAS INFLUENTIAL CHILEAN POET PABLO NERUDA POISONED?

Forensic investigation uncovers evidence that a lethal bacterium could have been in his body when he died.

By Michele Catanzaro

Scientists have concluded that renowned poet Pablo Neruda, a member of the Chilean communist party, might have had a toxic bacterium in his system when he died.

The finding is the latest in a decades-long investigation into the exact cause of Neruda's death on 23 September 1973. Although the Nobel-prizewinning poet had advanced prostate cancer when he died, some have said that the timing of his passing – 12 days after general Augusto Pinochet overthrew the socialist government that Neruda supported – was no coincidence.

When announcing the new results on 13 February, Rodolfo Reyes, Neruda's nephew and a lawyer representing his family, said they were proof that his uncle had been poisoned. Remnants of *Clostridium botulinum*, a bacterium that can produce the deadly botulinum toxin, were found in Neruda's teeth, and they could have appeared there as the result of an injection, Reyes said. (Teeth have blood vessels in their roots, so pathogens circulating in a person's blood when they die could theoretically be preserved there.) This method of poisoning "grants the appearance of a natural death", Reyes told *Nature*.

Some of the researchers who helped with the investigation, however, say the evidence is far from conclusive. There is nothing in the science that proves he was poisoned, says Hendrik Poinar, a molecular geneticist at McMaster University in Hamilton, Canada. It's neither a "closed door" nor a "smoking gun", he adds.

A forensic search

In 2011, decades after Neruda's passing, his former driver Manuel Araya alleged in an interview that Neruda had received an unscheduled injection a few hours before dying. Shortly afterwards, the Chilean communist party filed a complaint, saying that Neruda had been poisoned by Pinochet's regime.

> **"Technology has changed dramatically in the last few years. There was no way of doing this seven years ago."**

A judge ordered the exhumation of Neruda's remains and chose an international panel of specialists to analyse them. In 2013, that panel reported that it had screened the remains for some 2,000 chemical agents, such as arsenic, but did not find any evidence of poisoning.

Two years later, the judge organized a second panel to search for any evidence of biological poisons among the remains. That panel – made up of researchers from McMaster University, the University of Copenhagen, and other institutions – found DNA fragments from *C. botulinum* in Neruda's teeth.

To determine whether the neurotoxin-producing bacterium was in Neruda's body at the time of his death, or whether it was a contaminant that entered from the soil afterwards, the same laboratories continued the investigation. Their work culminated in the latest report, issued to a judge on 15 February. Because the judge has not released the results publicly, *Nature* spoke to some of the scientists who conducted the work.

They say they started by using a technique called shotgun metagenomic sequencing to study human and bacterial DNA extracted from Neruda's bones and teeth. The researchers compared the degradation of the DNA from *C. botulinum* with the degradation of Neruda's own DNA and that of other bacteria in his mouth. They found that the degradation patterns were similar, suggesting that *C. botulinum* could have been in Neruda's body around the time he died.

"Technology has changed dramatically in the last few years. There was no way of doing [all] this seven years ago", Poinar says.

Ruling out the possibilities

Still, the scientists caution against making any strong conclusions from their investigation so far.

"An injection is not the only possible explanation," says Marie-Louise Kampmann, a forensic geneticist at the University of Copenhagen who was part of the panel. For instance, "one alternative would be eating the bacteria in poisoned food", because *C. botulinum* can grow in improperly canned foods, she says.

Kampmann also acknowledges that comparing levels of DNA degradation cannot rule out that the bacterium entered the body after Neruda's death. One DNA sample that has been in a warm, humid environment for only 10 years might have the same amount of degradation as one that's been in a cold, dark setting for 50 years, she says, so comparisons can be deceiving.

Carles Lalueza Fox, an ancient-DNA researcher and director of Barcelona's Natural Sciences Museum in Spain, who was not involved in the studies, agrees. "One cannot completely rule out that the bacteria penetrated in the teeth after death," he says.

The scientists hope the judge will allow more research to be carried out. "We have worked with a heavily degraded and only partial genome," Poinar says. The panel managed to piece together one-third of the bacterial DNA sequence extracted from Neruda's teeth.

In that sequence, the researchers identified a gene that was responsible for producing the botulinum toxin, although they did not find evidence of the toxin itself. "A follow-up is needed to be sure about the presence of [additional] toxic genes" because not all strains of *C. botulinum* produce the toxin, Poinar adds.

It is unclear whether the judge will order further investigations or use the findings to issue a ruling. No deadline has been set for a decision.

ELECTRODES BUILD THEMSELVES INSIDE THE BODIES OF LIVE FISH

Conductive material that forms using the body's own chemistry could improve implantable electronics.

By Myriam Vidal Valero

An injectable gel tested in living zebrafish can use the animals' internal chemistry to transform into a conductive polymer.

The discovery, reported on 23 February in *Science* (X. Strakosas *et al. Science* **379**, 795–802; 2023), could lead to the development of electronic devices that can be implanted into body tissues such as the brain without causing harm.

When the gel is mixed with the recipient's own metabolites — chemicals generated by the body's processes — a chain reaction turns it into a solid but flexible material.

"We are performing a lot of experiments with these materials to grow electrodes and electronics around cells," says study co-author Magnus Berggren, a materials scientist at Linköping University in Sweden. He adds that the work could ultimately improve technologies for deep-brain stimulation, for example, or help damaged nerves to regrow.

Internal electronics

Electronic devices or circuitry that can be implanted in the body have many potential applications in medicine and research, such as helping the brain to communicate with prosthetic limbs, or even enhancing memory. But conventional electronic materials can cause inflammation or scarring, and they often deteriorate inside living tissue and eventually stop working.

Although there has been progress towards developing soft, flexible electrodes, it is difficult to get them into the body in a non-invasive way, says Berggren. If you want to insert something deep into the brain, for example, "you will basically make it cut all the way through", he says.

Berggren's team wanted to create a material that was conductive, but stable in the long term, non-toxic and of a consistency that allows it to be injected.

The mixture they developed contains the chemical building blocks for a conductive polymer, along with enzymes. When injected into living tissue, the gel reacts with the common metabolites glucose and lactate, which causes the gel to polymerize into a much firmer — although still soft — material. Working with a group led by chemical biologist Roger Olsson at Lund University in Sweden, the researchers used this approach to generate polymer 'electrodes' inside the fins and brains of living zebrafish (*Danio rerio*). They also used it in the nervous tissue of leeches and in muscle tissue from chickens, pigs and cows.

Because the material doesn't polymerize until it is inside the body, and is "compliant, soft and biocompatible", it eliminates mechanical differences between typical electrode materials and living tissue that make some medical implants so invasive, says Timir Datta-Chaudhuri, an electrical engineer at the Feinstein Institutes for Medical Research in Manhasset, New York.

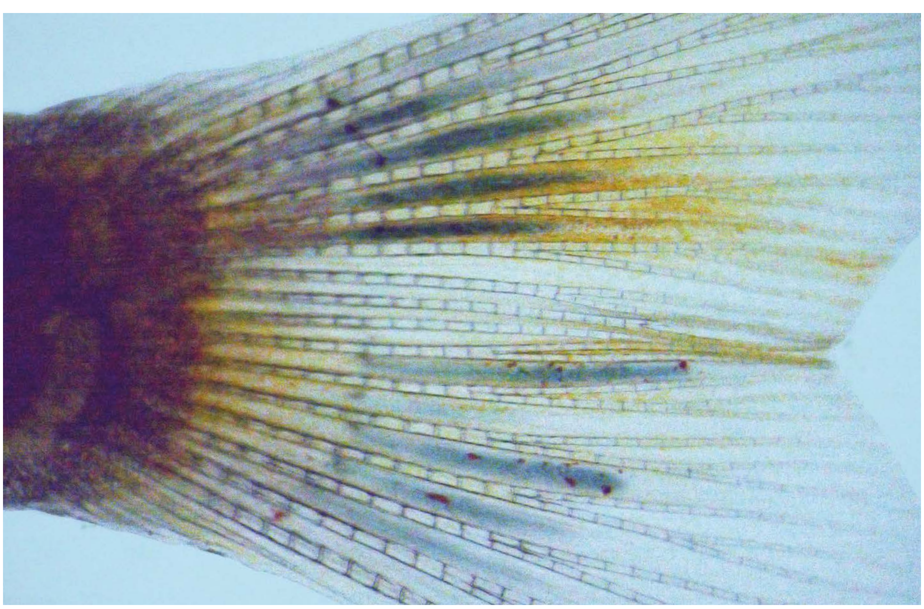
Alternative approach

The idea of using a living tissue's chemistry to create a conducting material inside the body is not new. In 2020, researchers reported engineering an enzyme to be expressed in genetically modified neurons in the nematode worm *Caenorhabditis elegans*. This caused the cells to produce conductive polymers (J. Liu *et al. Science* **367**, 1372–1376; 2020).

That approach could not be used in people, says Sahika Inal, a bioengineer at the King Abdullah University of Science and Technology in Thuwal, Saudi Arabia. For her, the value of the latest research is that the gel reacts with substances that the body produces naturally, and it does not require the organism to be genetically modified. "I think this technology is providing alternative thinking. Instead of changing the same device's software, why don't we just completely get rid of that device and make the device inside the cell?"

There are still many barriers to be overcome before the injectable substance can be tested in people. Even though the polymer is highly conductive, for example, there is currently no way to make it functional by connecting it to an outside electricity source.

The researchers also need to do more tests to establish that the approach is safe. They didn't observe any unusual behaviour in the zebrafish after injecting the solution into their brains, but they monitored the animals for only three days after the procedure. "They need to look at long-term chronic responses," says Inal.



X. STRAKOSAS *ET AL.*/*SCIENCE*

Conductive polymers (blue) formed in the tail fins of living zebrafish.