Physics

Mystery of the quantum lentils: Are legumes exchanging secret signals?

For 100 years, we have puzzled over the purpose of biophotons, low-level radiation emitted by all plants. Precision studies of lentils now hint that it could be a form of quantum communication

12 December 2023

By Thomas Lewton

Spooky Pooka

In the foothills to the south of Rome sits Italy's premier nuclear physics lab, the National Laboratory of Frascati. It has all the equipment you would expect at a cutting-edge science facility, with huge magnets, powerful particle accelerators and exposed electric cables spilling out everywhere. Many of the researchers here are trying to unpick the secrets of the standard model, our best theory of how reality works at its most fundamental level. And then there is the room where Cătălina Curceanu is monitoring a small box of lentils.

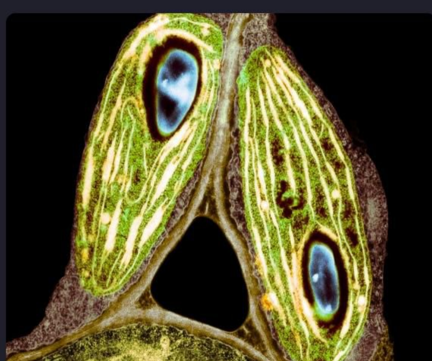
Granted, it isn't exactly normal behaviour for a physicist, but Curceanu hopes the apparatus and methods of nuclear physics can solve the century-old mystery of why lentils – and other organisms too – constantly emit an extremely weak dribble of photons, or particles of light. Some reckon these "biophotons" are of no consequence. Others insist they are a subtle form of lentil communication. Curceanu leans towards the latter camp – and she has a hunch that the pulses between the pulses might even contain secret quantum signals. "These are only the first steps, but it looks extremely interesting," she says.

There are already hints that living things make use of quantum phenomena, with inconclusive evidence that they feature in photosynthesis and the way birds navigate, among other things. But lentils, not known for their complex behaviour, would be the most startling example yet of quantum biology, says Michal Cifra at the Czech Academy of Sciences in Prague. "It would be amazing," says Cifra. "If it's true." Since

There are already hints that living things make use of quantum phenomena, with inconclusive evidence that they feature in photosynthesis and the way birds navigate, among other things. But lentils, not known for their complex behaviour, would be the most startling example yet of quantum biology, says Michal Cifra at the Czech Academy of Sciences in Prague. “It would be amazing,” says Cifra. “If it’s true.” Since so many organisms emit biophotons, such a discovery might indicate that quantum effects are ubiquitous in nature.

Biophotons

Biophotons have had scientists stumped for precisely a century. In 1923, biologist Alexander Gurwitsch was studying how plant cells divide by placing onion roots near each other. The closer the roots were, the more cell division occurred, suggesting there was some signal alerting the roots to their neighbour’s presence. It would be useful for plant roots to signal in this way, says Cifra, because it would tell them if other plants were germinating nearby, suggesting a fertile growing space.



From photosynthesis to navigation, life may exploit quantum effects

There is tantalising evidence to suggest that photosynthesis in some bacteria depends on quantum coherence and birds’ amazing feats of navigation rely on entanglement

To tease out how the onion roots were signalling, Gurwitsch repeated the experiment with all manner of physical barriers between the roots. Wood, metal, glass and even gelatine dampened cell division to the same level seen in single onion roots. But, to Gurwitsch’s surprise, a quartz divider had no effect. Compared to glass, quartz allows far more ultraviolet rays to pass through. Some kind of weak emission of UV radiation, he concluded, must be responsible.

Spooky Pooka

Living organisms have long been known to communicate using light. Jellyfish, Living organisms have long been known to communicate using light. Jellyfish, mushrooms and fireflies, to name just a few, glow or emit bright flashes to ward off enemies or attract a mate. But these obvious signals, known as bioluminescence, are different to the effect Gurwitsch had unearthed. Biophotons are "a very low-intensity light, not visible to the naked eye", says Curceanu's collaborator Maurizio Benfatto. In fact, biophotons were so weak that it took until 1954 to develop equipment sensitive enough to decisively confirm Gurwitsch's idea.

Since then, dozens of research groups have reported cases of biophoton emission having a useful function in plants and even animals. Like onion roots, yeast cells are known to influence the growth rate of their neighbours. And in 2022, Zsolt PÓnya and Katalin Somfalvi-TÓth at the University of Kaposvár in Hungary observed biophotons being emitted by sunflowers when they were put under stress, which the researchers hoped to use to precisely monitor these crops. Elsewhere, a review carried out by Roeland Van Wijk and Eduard Van Wijk, now at the research company MELUNA in the Netherlands, suggested that biophotons may play a role in various human health conditions, from ageing to acne.

There is a simple explanation for how biophotons are created, too. During normal metabolism, chemical reactions in cells end up converting biomolecules to what researchers called an excited state, where electrons are elevated to higher energy levels. Those electrons then naturally drop to their ground state and emit a photon in the process. Because germinating seeds, like lentils, burn energy quickly to grow, they emit more biophotons.

Today, no one doubts that biophotons exist. Rather, the dispute is over whether lentils and other organisms have harnessed biophotons in a useful way. "It's intriguing," says Greg Scholes at Princeton University. "Could that emission be used as a signal?"

Quantum biology

The idea is unproven, to be clear, but it isn't as far-fetched as you might think. We know that plants communicate using chemicals and sometimes even emit ultrasonic squeaks when stressed. This allows them to control their growth, warn each other about invading insects and attract pollinators. We also know they have ways of detecting and responding to photons in the form of regular sunlight. "Biological systems can detect photons and have feedback loops based on that," says Scholes. He adds that it isn't unreasonable to think that, if they have systems to detect photons of light, they could have ways of detecting weaker biophotons too. One idea is that this signal could tell cells to somehow metabolically reset en masse, says Scholes. "We don't really know how it works."

Cifra was once an advocate of biophoton signalling, but his enthusiasm waned in recent years when he uncovered more mundane explanations for many of the reports. Last year, for instance, he noticed that one claim of how biophotons affect cell death was actually explained by chemical signalling that hadn't been adequately blocked out. In another recent study, he found only a small difference between the pattern of biophotons being emitted by mung beans and that of a random signal generated by a computer. "I'm not sure that's enough to make it useful for communication," he says, though he acknowledges the emission is so weak that it is hard to be sure.

But Curceanu and Benfatto are hoping that the application of serious physics equipment to this problem could finally let us eavesdrop on the legume's secrets. They typically use supersensitive detectors to probe the foundations of reality. Now, they are applying these to a box of 75 lentil seeds – they need that many because if they used any fewer, the biophoton signals would be too weak.

Quantum coherence

The pair also knew that there was a possibility of the signals having some quantum characteristics. Quantum particles, which include photons, behave according to the rules of quantum theory, which describes the often counterintuitive behaviour of

Quantum coherence

The pair also knew that there was a possibility of the signals having some quantum characteristics. Quantum particles, which include photons, behave according to the rules of quantum theory, which describes the often counterintuitive behaviour of atoms and subatomic particles. For example, photons can exist in a nebulous cloud of many possible states called a quantum superposition. In this case, the photons are said to exhibit quantum coherence.

Quantum experiments add weight to a fringe theory of consciousness

Experiments on how anaesthetics alter the behaviour of tiny structures found in brain cells bolster the controversial idea that quantum effects in the brain might explain consciousness

Years ago, Benfatto came across a paper on biophotons and noticed there appeared to be patterns in the way they were produced. The intensity would swell, then fall away, almost like music. This gave him the idea of applying a method from physics called diffusion entropy analysis to investigate these patterns. The method provides a means of characterising the mathematical structures that underlie complex patterns. Imagine comparing a simple drumbeat with the melody of a pop song, for example – the method Benfatto wanted to apply could quantify the complexity embodied in each.

To apply this to the lentils, Benfatto, Curceanu and their colleagues put their seeds in a black box that shielded them from interference. Outside the box, they mounted an instrument capable of detecting single biophotons. They also had rotating filters that allowed them to detect photons with different wavelengths. All that remained was to set the lentils growing. “We add water and then we wait,” says Benfatto.

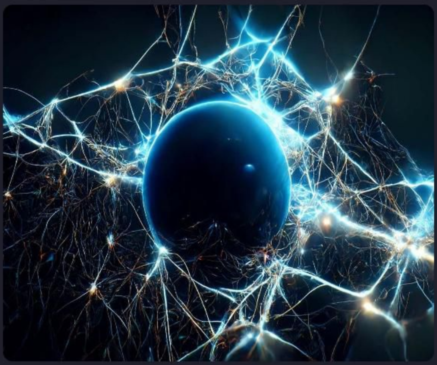
In 2021, they unveiled their initial findings. It turned out that the biophotons’ signals changed significantly during the lentils’ germination. During the first phase, the photons were emitted in a pattern that repeatedly reset, like a piece of music changing tempo. Then, during the second phase, the emissions took the form of another kind of complex pattern called fractional Brownian motion.

The fact that the lentils' biophoton emissions aren't random is an indication that they could be communicating, says Benfatto. And that's not all. Tantalisingly, the complexity in the second phase of the emissions is mathematically related to the equations of quantum mechanics. For this reason, Benfatto says his team's work hints that signals displaying quantum coherence could have a role in directing lentil germination.

Cifra warns that claims about the nature of these signals shouldn't be made based merely on mathematical similarities. Just because something can be described by quantum-style maths, that doesn't in itself prove the thing is quantum by nature. Curceanu recognises that any sign of quantum effects is still tentative. "There's something going on there, but we can't claim to know what," she says.

Cifra reckons that quantum mechanics is likely to play an important role in biology – for example, in bird navigation – just not through biophotons. The quantum interpretation of the lentils research is "a stretch", he says. "It can easily be explained by classical effects. I give preference to the simpler explanation."

Part of the problem with designing experiments like these is that we don't really know what quantum mechanical effects in living organisms look like. Any quantum effects discovered in lentils and other organisms would be "very different to textbook quantum mechanics", says Scholes.



Why nature is the ultimate quantum engineer

Historically, researchers believed that quantum properties disappear at the scale of biology, but there is increasing evidence that this isn't the full story, says physicist Clarice Aiello

Then there is the question of why quantum mechanics would be useful to lentils at all. Finding quantum effects in biophotons would be a "big deal", says Scholes, "but it's an open question about what would the function be". What evolutionary advantage, in other words, would using quantum signals confer on a lentil? One way to think about this might be with reference to the difference between the workings of a classical computer, which uses bits, and a quantum computer, which uses quantum bits. The two systems work in different ways that mean they are suited to solving different kinds of problems. Perhaps, similarly, any quantum signals passing between the pulses would give them a unique way of sending information – for a purpose we haven't yet fully discerned.

Another possibility is that quantum communication enables lentils to get messages through without these getting lost in transmission. Since biophotons are emitted by all living things, the lentils' signals could be swamped by emissions from surrounding organic matter, says Cifra. It is possible, says Scholes, that quantum coherence could enable the signals to pass through, despite this background noise.

Benfatto admits that, so far, the evidence for quantum lentils is sketchy. Still, he is pushing ahead with a new experimental design that makes the signal-to-noise ratio 100 times better. If you want to earwig on the clandestine whispers of these seeds, it might just help to get rid of their noisy neighbours, which is why he will study one germinating lentil at a time.