Are we ready for quantum biology?

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In *Life on the Edge*, Jim Al-Khalili and Johnjoe McFadden argue quantum effects are decisive in biology – but this challenging idea needs more proof. FOR 15 years, theoretical physicist Jim Al-Khalili and molecular geneticist Johnjoe McFadden have been discussing how quantum physics, the science of the incredibly small, might affect biology.

This energetic but frustrating book is the outcome of their many discussions. By explaining the fundamentals of quantum mechanics, and exploring recent theories and findings, they aim to convince the reader that quantum effects are more than simply the deep substrate on which biology exists – without recourse to a single equation.

They open with the example of the European robin, Erithacus rubecula. Every autumn the birds migrate from Sweden to the Mediterranean, using magneto-reception to navigate. This extraordinary sense involves a chemical called cryptochrome, which is found in many birds and insects. It even exists in maggots.

Al-Khalili and McFadden argue that this remarkable ability is based on quantum entanglement, and much evidence points this way. But we have yet to identify the underlying mechanism, or mechanisms, and the science is less settled than readers may think as they are transported by the authors' enthusiasm.

Similarly, Al-Khalili and McFadden devote a chapter to what they admit is a controversial quantum theory of olfaction. The vast majority of smell scientists consider that our olfactory receptors detect aspects of the molecular shape of an odour – its size, functional group and so on. The problem is that no one has been able to show how this works, nor are we even sure exactly what is detected: is it the smell itself, or smell plus molecular chaperone?

In contrast to this dominant view, there have been suggestions over the years that "quantum tunnelling" in our noses is responsible, and there has been an occasionally acrimonious debate over the validity of these theories. As Al-Khalili and McFadden acknowledge, resolving this issue will involve studying the crystal structure of the receptors (this is very difficult), but they emphasise that the only theoretical explanation for our sense of smell is the quantum one.

As an experimentalist, I am less impressed by the power of theory and would have preferred to see the authors revelling in our current ignorance. After all, the most important words in science are "we don't know".

Some of quantum mechanics' apparently successful forays into biology described in the book are those focusing on how enzymes work and on photosynthesis. Even here, however, the significance of these interpretations is still debated – in particular, it remains unclear how decisive a part quantum entanglement plays in plant biology.

One of the most influential people to link quantum physics and biology was Erwin Schrödinger himself, whose book What is Life? inspired, among others, DNA pioneers James Watson and Francis Crick. Al-Khalili and McFadden discuss Schrödinger's ideas on mutation in some detail, but do not get to their origin.

In fact, Schrödinger's view was based on biophysicist Max Delbrück's theory, put forward in the so-called Three Man Paper, written with geneticist Nikolay Timofeev-Ressovsky and biophysicist Karl Zimmer in 1935.

Schrödinger argued that if Delbrück's view of mutation was wrong, then "we should have to give up further attempts", meaning we would have to give up on using physics to explain genes. Delbrück's approach was correct only at the most general level, and the discovery of the nature of mutations did not refer to his ideas at all.

Quantum letters

In their chapter on genes, Al-Khalili and McFadden boldly argue that genes "are written in quantum letters" because quantum effects underlie the hydrogen bonds that hold the DNA double helix together.

This is an example of the kind of trivial involvement quantum physics has in biology which most of the book avoids: quantum effects lie beneath all molecular structures, but that does not mean that we can explain all phenomena in terms of quantum equations. Quantum physics played no part in cracking the genetic code, nor is it necessary to understand how it functions.

The great virtue of this book is its thesis – it sets out a clear and enthusiastic argument for the importance of quantum biology. The subtitle proclaims that quantum biology is coming of age. It can equally be argued that it is still taking its first steps.

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