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Every year, around about this time, thousands of European robins escape the oncoming harsh Scandinavian winter and head south to the warmer Mediterranean coasts. How they find their way unerringly on this 2,000-mile journey is one of the true wonders of the natural world. For unlike many other species of migratory birds, marine animals and even insects, they do not rely on landmarks, ocean currents, the position of the sun or a built-in star map. Instead, they are among a select group of animals that use a remarkable navigation sense – remarkable for two reasons. The first is that they are able to detect tiny variations in the direction of the Earth's magnetic field – astonishing in itself, given that this magnetic field is 100 times weaker than even that of a measly fridge magnet. The second is that robins seem to be able to "see" the Earth's magnetic field via a process that even Albert Einstein referred to as "spooky". The birds' in-built compass appears to make use of one of the strangest features of quantum mechanics.

Over the past few years, the European robin, and its quantum "sixth sense", has emerged as the pin-up for a new field of research, one that brings together the wonderfully complex and messy living world and the counterintuitive, ethereal but strangely orderly world of atoms and elementary particles in a collision of disciplines that is as astonishing and unexpected as it is exciting. Welcome to the new science of quantum biology.

Quantum effects were certainly not expected to play any role inside the warm, wet and messy world of living cells, so most biologists have thus far ignored quantum mechanics completely, preferring their traditional ball-and-stick models of the molecular structures of life. Meanwhile, physicists have been reluctant to venture into the messy and complex world of the living cell; why should they when they can test their theories far more cleanly in the controlled environment of the lab where they at least feel they have a chance of understanding what is going on?

Yet, 70 years ago, the Austrian Nobel prize-winning physicist and quantum pioneer, Erwin Schrödinger, suggested in his famous book, *What is Life?*, that, deep down, some aspects of biology must be based on the rules and orderly world of quantum mechanics. Schrödinger proposed that there was something unique about life that distinguishes it from the rest of the non-living world. He suggested that, unlike inanimate matter, living organisms can somehow reach down to the quantum domain and utilise its strange properties in order to operate the extraordinary machinery within living cells.

Recent research indicates that some of life's most fundamental processes do indeed depend on weirdness welling up from the quantum undercurrent of reality. Here are a few of the most exciting examples.

Enzymes speed up chemical reactions so that processes that would otherwise take thousands of years proceed in seconds inside living cells. Life would be impossible without them. But how they accelerate chemical reactions by such enormous factors, often more than a trillion-fold, has been an enigma. Experiments over the past few decades, however, have shown that enzymes make use of a remarkable trick called quantum tunnelling to accelerate biochemical reactions. Essentially, the enzyme encourages electrons and protons to vanish from one position in a biomolecule and instantly rematerialise in another, without passing through the gap in between – a kind of quantum teleportation.

Another vital process in biology is of course photosynthesis. The initiating event is the capture of light energy by a chlorophyll molecule and its conversion into chemical energy that is harnessed to fix carbon dioxide and turn it into plant matter. The process whereby this light energy is transported through the cell has long been a puzzle because it can be so efficient – close to 100% and higher than any artificial energy transport process.

The first step in photosynthesis is the capture of a tiny packet of energy from sunlight that then has to hop through a forest of chlorophyll molecules to makes its way to a structure called the reaction centre where its energy is stored. The problem is understanding how the packet of energy appears to so unerringly find the quickest route through the forest. An ingenious experiment, first carried out in 2007 in Berkley, California, probed what was going on by firing short bursts of laser light at photosynthetic complexes. The research revealed that the energy packet was not hopping haphazardly about, but performing a neat quantum trick. Instead of behaving like a localised particle travelling along a single route, it behaves quantum mechanically, like a spread-out wave, and samples all possible routes at once to find the quickest way.

All these quantum effects have come as a big surprise to most scientists who believed that the quantum laws only applied in the microscopic world. So how does life manage its quantum trickery? Recent research suggests that rather than avoiding molecular storms, life embraces them, rather like the captain of a ship who harnesses turbulent gusts and squalls to maintain his ship upright and on course.

Just as Schrödinger predicted, life seems to be balanced on the boundary between the sensible everyday world of the large and the weird and wonderful quantum world, a discovery that is opening up an exciting new field of 21st-century science.