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Where does life come from?

Classical physics has no answer to this question; time to make quantum leap

By Vlatko Vedral

LIFE presents a great mystery to a scientist.

Where does it come from? How did it appear in the first place? Does it exist elsewhere in the universe?

The questions just keep on coming.

Living beings are extremely well adapted to their surroundings.

Even the simplest of organisms, such as bacteria, know how to survive by finding appropriate food, digesting it and turning it into energy, which they then use to move into a more desirable environment and reproduce.

Try designing a machine to do this.

Our most sophisticated computers look ridiculously simple when compared to even the lowliest of bacteria, let alone the infinite complexity of a human being.

There is no way that your laptop, not even a Pentium 100, can plug itself into an electrical outlet, let alone find a suitable mate and go into a safe drawer to make a baby laptop.

That is why scientists are baffled: How is any living thing so much better designed and robust than any humanly engineered machine?

It is therefore not surprising that the Austrian Nobel laureate Erwin Schrodinger speculated more than half a century ago that living beings may not be explained by the laws of physics.

Ordinary laws of physics, such as the belief that everything that exists has energy, occupies space and evolves in time, may describe non-living matter successfully. When it comes to life forms however, this might not suffice.

An international conference I organised here recently was meant to explore Dr Schrodinger's suggestion.

What could those other laws be?

Large objects in physics are described by what we call classical physics.

If you want to know what happens to a baseball when you hit it with a bat, you have to use classical laws on force, mass and acceleration to find out.

Understanding how present computers operate can also be achieved using classical physics.

Biological objects are large. Bacteria, though small, still consist of hundreds of thousands of atoms – the smallest particle that can exist on its own. We use classical laws to understand them.

If you want to know how bacteria react to being stretched, for example, it will suffice to use classical laws of vibrations which use concepts such as mass, force and acceleration to correctly predict the response.

Recently, however, biologists have begun to realise that classical laws cannot explain everything.

Enter two participants of my conference: biologists Wolfgang Wiltschko and Graham Fleming.

Dr Wiltschko, of the University of Frankfurt, Germany, catches birds and experiments on their ability to measure the earth's magnetic field.

Birds need to be able to sense this field so that when it gets cold, they have the ability to escape the freezing parts of northern Europe, for example, by flying to the warmer equatorial parts of Africa.

It was initially thought that birds, along with other animals that respond to magnetic fields, have small natural "compasses" made up of little molecular magnets inside their beaks.

The compass, of course, can be fully understood with the basic classical physics of magnetic fields.

Dr Wiltschko's extensive studies over the past 20 years seem to suggest there are no internal compasses in his birds.

So how do they migrate across continents?

Dr Fleming, of the University of Berkeley in California, studies something even more fascinating: photosynthesis. This is the process by which plants convert the sun's light into energy inside their cells, and survive under diverse conditions.

As a by-product of photosynthesis, plants get rid of oxygen, releasing it into the atmosphere.

We all need oxygen to live, so without photosynthesis, there would simply be no life around.

The annoying thing, as Dr Fleming recently discovered, is that the super-high efficiency of plants cannot be understood with classical physics either. It is at present impossible to build a machine that could do what plants do.

Yet if we could utilise the sun's light with the same efficiency as plants, we would not be worried about running out of fossil fuels in 20 years' time.

The answer to both conundrums could be that we need to use quantum physics to explain both birds and plants.

Quantum physics, in contrast to classical physics, was designed to describe small systems, like individual electrons – components of atoms.

According to quantum mechanics, electrons have a bizarre feature which allows them to be in many different positions at the same time.

An electron can be located near one atom and at the same time be close to another one!

This is why quantum physics ought to look out of place in biology – your orchid is either in your room or on your balcony, but not in both places at the same time.

Yet, from experiments by people like Dr Wiltschko and Dr Fleming, a picture is now emerging.

It is possible that both birds and plants utilise the ability of certain molecules to exist in different locations simultaneously.

This, it would seem, allows them to be surprisingly efficient in orientation and energy combustion, as they can use limited resources in several ways at once.

To give a better feel of how this works, think of the main problem of photosynthesis as follows.

When light hits the surface of a plant, it dislocates electrons inside plants. These electrons all need to go to the same place to convert the sun's energy into chemical processes that fuel plant cells. Finding this place is difficult for electrons as they have to "search" many possible sites inside cells.

Here is where quantum mechanics helps speed things up. Since an electron exists in many locations at the same time, one of these will be the correct place for chemical reactions!

Where does this leave us?

Once all experimental evidence is rigorously analysed, and if the two scientists are fully vindicated, we will have to conclude that life on earth would not exist as we know it without the laws of quantum physics.

Can we conclude even more from the fact that quantum mechanics is needed to understand living systems?

One of the biggest mysteries we face is to explain how life arose in the first place.

If it really happened by chance, then the odds for this are stupendously low, because even the simplest life form has billions and billions of atoms which all had to be combined in the right way for this to happen.

But quantum physics might be able to increase the odds in our favour...the search for the right molecules to support life by replication could turn out to be much more efficient using quantum mechanics in the same way that it speeds up the electron's energy conversion in photosynthesis.

So keep your eyes peeled.

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