

How Quantum is Life? The Parallels between Biology and Quantum Physics Biology and quantum physics are often portrayed as two entirely different approaches to science. Biology is a non-mathematical description of living things which operates at a scale that can be directly observed in a conventional and common-sense way. Quantum physics is a mathematical theory of fundamental things which operates at a sub-microscopic scale, so that those things can only be inferred, and provides statistical probabilities of events with some very bizarre predictions.

I loved biology when I was at school. I saw it as a description of life and, as such, it was magical. Underneath the common-sense descriptions of how bodies and plants worked lay something strange and unknown—life itself. Understanding life seemed a worthwhile and important quest. It was only later, when I became interested in quantum physics (for much the same reasons: it was something magical that described fundamentally how the world worked), that I began to realize the similarities and connections between life, as understood by biology, and the fundamental nature of the world, as understood by quantum physics. Were these parallels just coincidental, or did these two apparent disparate disciplines share some hidden key to the riddle of nature? Could quantum physics actually be describing life: could life be quantum?

Patterns The animals and plants studied in biology are living things, but just like rocks and other inanimate objects, they consist of atoms that are usually combined into molecules. These molecules are often in a constant flux: for example, we breathe in oxygen which is converted to carbon dioxide in our bodies, and which we then breathe out. But even though many of the molecules that make up a particular organism are replaced with other molecules over time, it still remains the same organism. Moreover, if those same molecules were to be substantially rearranged, it would quite likely result in something that was no longer alive. Curiously, it seems it is not the constituents of things that give them life, but rather the pattern of those constituents.

Quantum theory studies inanimate fundamental things. It is a mathematical theory so, although it has to predict the correct probabilities of certain events happening (get the numbers right), it does not have to contain an explanation of why it works. It is like a list of procedures to follow to get the right answer without there being any obvious reason as to why those procedures work, even if they work incredibly well. In biology, this would be similar to knowing what proportion of people in a population will die during an outbreak of a particular disease without knowing the cause of the disease or why it kills people. So, in this sense, quantum theory is not understood, and to resolve this problem, various explanations of why quantum theory works have been put forward; however, there is no general agreement as to which of these is correct.

In quantum physics, a particle has a wavefunction which ultimately gives the probability of a particle being found at a particular place at a particular time; there is then a pattern of probabilities spread through space that varies with time but is characteristic of the particle in question, for example, a photon will have a different pattern of probabilities to an electron. These values then determine where and when a detection is most likely to be made in the case of an experimental apparatus, or a perception most likely to become apparent in the mind of a human being. So, every fundamental particle has a group of wavefunction values that begins at the point of a detection and then spreads through space. In the case of an electron, these values would appear and spread after the electron is detected, only to disappear at the next detection (in what is known as the collapse of the wave function), with a new set of values developing from the point of that detection. With repeated detections, one set of values can then be repeatedly replaced by another, with each group following the same pattern which can ultimately lead to a change in the subjective perceptions of our consciousness, such as the colours we see.

Conventionally, these values are used to calculate probabilities and are mathematical abstractions, but what if they actually describe the changes in something real? That something would then need to exist at every point in space and be able to change. Quantum physics would then be a description of how that same something changes over time, i.e. a description of change rather than a description of what it is that is changing. A theory that simply describes change might seem strange, but in an analogous way, a television represents the outside world with a changing pattern of pixels on a screen even though pixels are not what material things are really made of. However, the way those pixels change does accurately represent the way things are changing in the actual world, and this, it seems, is all that is required for the television to serve its purpose. So, with both quantum physics and the workings of the television, it is how things are changing

that is important rather than the real nature of those things. Paradoxically, it would seem we can live effectively in our world by knowing how things change, without knowing what those things fundamentally are. Our knowledge of reality can then legitimately consist of patterns of wavefunction values that evolve and repeat, and the world can be described by patterns of changing values.

In biology, life is a pattern, and in quantum physics, if interpreted in the right way, the rest of nature also consists of patterns. Patterns are then primary and objects secondary, with objects emerging from patterns. The world then fundamentally consists of patterns rather than material things.

Birth, death and reproduction A characteristic feature of biological systems is that they reproduce. All living things are born and then all living things die—it is the circle of life. That circle is maintained by reproduction. According to the laws of thermodynamics, things become more disordered with time, and living things need to overcome this increasing disorder to survive. One method to achieve this is by reproduction. New and perfectly ordered organisms can be constantly generated by reproduction, effectively reversing the imminent disorder of ageing and death. In the language of thermodynamics: there is increasing entropy in biological systems which is overcome by a sudden decrease in entropy with the birth of a new organism.

Reproduction might seem a peculiarly biological characteristic, but it is also very much a part of certain interpretations of quantum physics. The values of a wavefunction are born at a detection; they then change and spread out as time progresses, only to die at the next detection as a new set of values are born—they reproduce. In this way, the patterns of values that represents a specific particle, such as an electron, can move from place to place and persist, and maintain themselves against the laws of thermodynamics and entropy by the constant creation inherent in reproduction. The idea of creation then describes not only the initial creative event of the Big Bang, but also an ongoing chain of creative events that allows the patterns of fundamental particles to reproduce themselves and survive.

Simplicity and evolution Although living things are enormously complicated, underneath that complexity lies a beautiful simplicity. To take human beings as an example: every human is coded for by their DNA, with that code simply consisting of four bases: Adenine (A), Guanine (G), Cytosine (C), and Thymine (T). These simple A, G, C and Ts are then repeated an enormous number of times. A human genome consists of approximately 3 billion base pairs, which translates to about 6 billion individual bases when considering both strands of the double helix that forms DNA. Complexity comes from this repeated simplicity. The resulting code gives a huge number of possible variations, and, therefore, a huge variety of human beings, and it is those that are best suited to their environment can then be selected to survive, allowing those humans to evolve with their environment.

But much the same seems to apply in quantum physics. A few equations can be used to make predictions in the physical world, but to describe anything except the simplest situation, they have to be repeatedly applied an innumerable number of times. Again, complexity comes from repeated simplicity.

There are also many possible patterns of values in quantum physics, however, it is only a few of those patterns that appear to have the capacity to reproduce and survive. For example, although there are a nearly infinite number of possible combinations of fundamental particles, there are only one hundred and eighteen of those combinations that form the elements of the periodic table, and only eighty of them that are stable (i.e. have at least one stable isotope) in the conditions found here on Earth. Just as living organisms are selected to survive by Darwinian natural selection, it appears that the patterns of quantum physics are also selected.

Consciousness A personal knowledge of life also comes down to a personal experience of what it is like to be conscious. There is a paradox here because the brain would seem to be the seat of consciousness but is made up of many individual brain cells, even though the personal experience is of a single consciousness—of just one person making decisions for which that person is accountable. Somehow, many different brain cells give the experience of one single person. However, something very similar can again be seen in quantum physics: when single particles are part of a group of particles, and if no measurements are made, the group can be seen as an entangled whole. Each particle is then a pattern of changing values that overlies the

patterns of other particles, with the values of all these different patterns combining into a single unified pattern. This unified pattern can then be used to predict all possible outcomes of the group until an actual outcome is measured.

Experiments in quantum biology Although biology is essentially non-mathematical, mathematics can still have a very useful role. In medicine, for example, the number of patients in a population that are likely to have a particular condition, such as cancer, can be calculated, and knowing these numbers can then be very helpful when designing studies of the disease and trials of treatment. But even more helpful is to know why a condition gives these probabilities, i.e. having a theory about what causes the condition and what causes it to progress. Such understanding can lead to much more insightful investigations.

The problem with quantum physics is that it gives probabilities, but then the cause of these probabilities, in terms of what is really happening in the natural world, is hotly disputed. Trying to design experiments in quantum biology then seems like putting the cart before the horse. An understanding of what the mathematics of quantum physics is really describing is needed first, otherwise the insights that experiments can give will be limited by that lack of understanding.

Conclusion Biology and quantum physics are clearly intimately connected, but quantum physics is still generally thought of as a useful way of understanding the sub microscopic inanimate parts of biology, such as the mechanism birds use to navigate during their migrations. However, there is something much bigger that quantum physics could contribute—an understanding of life itself. The problem then lies with the lack of an agreed interpretation of quantum physics, but perhaps biology, with its description of life, could help formulate that interpretation. Life would then be quantum and, paradoxically, the explanation of the inanimate (as described by quantum theory) found in life.