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The Entangled Universe

by Mae-Wan Ho

Einstein's work began a revolution that eventually dethroned the reigning model of physics. Could quantum theory have a similar effect on our understanding of life itself? Scientist Mae-Wan Ho tells us how this new science implies a unity in all of creation

Over the past 150 years, the field of biology has taken a distinct turn for the worse. It has become increasingly mechanistic and reductionist, which is why most biologists nowadays are hostile to holistic thinking or any hint of unity in nature.

Reductionism is the doctrine that complex systems can be completely understood in terms of their simplest parts. For example, a physical system is to be understood in terms of its atoms, an organism in terms of its genes, a society in terms of its individuals, and so on. Mechanical reductionism is a commitment to understand all complex phenomena in terms of simple entities that behave according to the laws and assumptions of mechanics.

With the advent of genetic engineering, mechanistic biology has reached its logical, nightmarish conclusion where organisms, including human beings, are to be genetically manipulated and cloned. Already, the genetic material of a human being has been injected into a cow's egg, with alarming implications.

Fortunately, there is a long overdue science of the organism that is taking shape. It takes biology beyond the mechanistic era, connecting it to the organic revolution that has been gathering momentum in the rest of Western science, especially within the past twenty years. This science of the organism restores all the qualities that have been exorcised from life and nature, thereby reaffirming and extending our intuitive, poetic, and even romantic notions of nature's unity.

I would like to convince you to reject reductionist biology, not just because of its inherent dangers, but because there are positive, rational, ecological, life- enhancing, fulfilling, and aesthetic reasons for embracing the organic alternative.

Escape from Plato's cave

Denis Diderot (1713–1784), encyclopedist, polymath, and major figure of the French Enlightenment, describes a dream he had after an evening spent reading Plato:

As in Plato's story, he finds himself imprisoned in a cave, sitting in the middle of a crowd of men, women, and children. Their hands and feet are in chains and their heads are clamped so they cannot look around. The majority are eating, drinking, laughing, and singing. They are not bothered in the least by their chains, even to the extent that they look with some hostility at those who try to free themselves or help others to do so. They have their backs to the entrance of the cave and are only able to look at the far end, where a great screen is hung.

Diverging from Plato's story, Diderot dreamt that standing behind him were kings, ministers, priests, doctors, apostles, prophets, theologians, politicians, rogues, charlatans, makers of illusions, and the whole troupe of merchants of hopes and fears. Every one of them has different colored slides and is projecting onto the great screen scenes that are so lifelike that the prisoners take them to be real.

Diderot adds that if an intelligent person grows suspicious and, with painful effort and contortion, overcomes the powers that keep his head turned and scales the wall to escape from the cave, "he had better take care if he ever returns to keep his mouth shut as to what he has seen…"

Diderot is inviting us to overcome the tyranny of powers that be, and the even greater tyranny of habit to see nature in ways that are dictated by intellectual laziness, convention, and "common" sense. Today, more than two centuries later, Diderot's dream may be read as an allegory for the rejection of the mechanistic worldview: we must turn around, escape from the cave, and see and experience the real world.

The 20th century has produced revolutionary scientific developments which have exposed the grand illusion of the mechanistic universe for what it was – abstract, projected images of reality. The first upset came when Einstein's relativity theory broke up Newton's universe of absolute space and time into a multitude of space-time frames in which space and time are no longer neatly separable. Furthermore, each space-time frame is tied to a particular observer. Thus, each observer has a unique clock and a unique map. Stranger still for Western science, quantum theory demanded that we stop seeing things as separate, solid objects with definite locations in space and time. Instead, we should see them as delocalized, indefinite, mutually entangled entities.

Two properties of quantum systems that pose the greatest difficulties for the mechanistic framework are quantum superposition and quantum non-locality. I will describe how these concepts relate to the science of the organism, but first let me explain what they are.

Schrödinger's cat

Quantum superposition is usually presented as the paradox of Schrödinger's cat (which is not at all kind to cats). In this parable, the cat is kept inside a box with an atom that has a probability to decay radioactively. When it does, it sends a signal that triggers cyanide gas to be released to kill the cat. According to quantum theory, unless and before the box is opened by someone (the observer), the cat is in a quantum superposition of being dead, being alive, and being both dead and alive simultaneously. This strange, indefinite quantum system can be described by a wave function of the quantum superposition of all the possibilities, and is real, in the sense that it can be experimentally created in many forms. However, once the indefinite quantum system is observed by a macroscopic, classical instrument such as a person, it suddenly collapses into a definite state. When the box containing Schrödinger's cat is opened, it ceases to be a quantum system, and the cat will be observed in one of two definite states: either dead or alive.

This collapse of the wave function is generally thought to represent a transition between the quantum and the classical domains – the former is a domain of elementary particles and the latter of ordinary macroscopic systems, like human beings and houses. However, not all physicists are happy with dividing the world up into quantum and classical domains. Many argue, as I do, that quantum physics actually applies to the whole of reality.

Non-local entanglement

Non-locality is usually presented as the Einstein, Podolsky, and Rosen paradox (the EPR paradox).
Although Einstein contributed a lot to quantum theory, he could never accept how the theory sometimes fails to describe reality, leading to many paradoxes, including quantum superposition. The intangible, indefinite quantum state bothered him, as it continues to bother many physicists. Something told Einstein that "God does not play dice!" He assumed there must be a deeper structure underlying quantum mechanics that can represent reality without the contradictions inherent in the accepted theory.

In order to try to show that this was the case, Einstein, Podolsky, and Rosen proposed a thought experiment, or gedanken experiment (which in the end overcame their objections, especially when the experiment was actually carried out). The experiment consists of elementary particles that are prepared in pairs and are allowed to move apart in opposite directions. According to quantum theory, if we measure a property of one of the pair, such as spin, the other of the pair would have a correlated property. For example, if the first particle is measured as spin up, we would find the other to be spin down; if the first is spin left, the second would be spin right, and so on. It would be so regardless of which property is measured, and no matter how far apart the particles are when the measurements are made.

The results cannot be explained by any model that involves local interactions, say, by a signal being sent from one particle and measured by the other. Such a signal, if it exists, would have to take no time at all to travel, which is considered impossible in classical physics. The conclusion that has to be drawn is that the effect of measurement (the collapse of the wave function) of one particle is somehow instantaneously communicated to the other one. Before measurement, neither particle actually had the definite property, and the separated particles comprised a single coherent system. The particles existed in a pure state (like Schrödinger's cat), and each particle in the pair could be described with an identical wave function.

By extrapolating the experimental results, the two particles could be light-years apart and still the collapse of the wave function of one particle instantaneously collapses that of the other.

Schrödinger introduced the concept of entanglement in 1935 to describe the phenomenon of non-locality. The two particles are, so to speak, entangled with each other in a pure, coherent state. "Entangled" is such a wonderful word to describe this inseparable oneness. The two particles do not even have to be prepared together so that they are originally one system. Experimentally, one can allow any two particles of matter, including big particles like neutrons and protons, to be produced at distant and unrelated sources. As soon as they have come together and have interacted, they become entangled with each other long after they have collided and separated. They have become one quantum system. Could it not be so for macroscopic particles like human beings?

And there is something else. It matters who does the observing and how. The potential observer and the observed are also entangled with each other. The so-called observer actually takes part in determining the outcome. Once the intention for observing is there, the entanglement begins. For example, the moment two people decide to attend a meeting, they have become entangled with one another, even though they could be on opposite sides of the globe. And once they have interacted, they shall remain entangled with one another long afterwards, perhaps ever after.

The universe of organisms

In the aftermath of quantum theory, English philosopher Alfred North Whitehead declared that physics had to be entirely rewritten in terms of a general theory of the organism. He proposed that inert objects with simple, definite locations in space and time do not exist. Instead, all nature is alive with process and happenings. The totality of all that happens is a pattern of flows and influences, now diverging from one locus, now converging towards another in such a way that "each volume of space, or each lapse of time includes in its essence aspects of all volumes of space, or of all lapses of time."

In Whitehead's organic universe, everything is an organism, from elementary particles such as photons and electrons to human beings and galaxies. Each organism is a field of coherent activities that draws on its experience of the environment to make itself whole, while aspects of itself are communicated to others. The realization and maintenance of self and other are thus completely intertwined. The self is delocalized over all that we experience, just as all that we experience is entangled within our being.

Crystal consciousness

Given this background, I propose that the organism is, in the ideal, a quantum superposition of coherent activities, with instantaneous, non-local intercommunication throughout the system.

My claims about the coherence of the organism are based on empirical findings from our own laboratory, as well as from established laboratories around the world. These are described in detail in the second edition of my book, The Rainbow and the Worm. Perhaps the most suggestive evidence for the coherence of the organism is our discovery, in 1992, that all living organisms are liquid crystalline.

The discovery is based on the polarized light microscopy that earth scientists have used to study mineral crystals and other materials with a high degree of molecular order, such as liquid crystals. A small modification of the optical system allowed us to look for crystalline molecular order in whole, living organisms such as the Drosophila larva, Daphnia, and brine shrimp. In this technique, color and its intensity indicate molecular structure and the degree to which the molecules are ordered. If there were no molecular order, no color would be generated in the images.

In the breathtaking color images we generated, one can see that the activities of the organism are fully coordinated in a continuum from the macroscopic to the molecular. The organism is coherent beyond our wildest dreams. Every part is in communication with every other part through a dynamic, tunable, responsive, liquid crystalline medium that pervades the whole body, from organs and tissues to the interior of every cell. Liquid crystallinity gives organisms their characteristic flexibility, exquisite sensitivity, and responsiveness, thus optimizing the rapid intercommunication that enables the organism to function as a coherent whole.

Life as an organism

With our new view of the coherent organism, think of each organism as an entity that is not really confined within the solid body we see. The visible body just happens to be where the wave function of the organism is most dense. Invisible quantum waves are spreading out from each one of us and permeating into all other organisms. At the same time, each of us has the waves of every other organism entangled within our own make-up.

In a very real sense, no person is alone, no man is an island. We are not isolated atoms, each jostling and competing against the rest in a Darwinian struggle for survival of the fittest. Instead each of us is supported and constituted, ultimately, by all there is in the universe. We are at home in the universe. In this entangled universe we cannot do violence to our fellow human beings or our fellow inhabitants of the Earth without doing violence to ourselves. And the most effective way to benefit oneself may be to benefit others.

Most of all we are not impotent observers outside nature, subject to the slings and arrows of outrageous fortune. Instead we are participants in the creation drama that is constantly unfolding. We are constantly co-creating and re-creating ourselves and other organisms in the universe, shaping our common futures, making our dreams come true, and realizing our potentials and our ideals.

Adapted from a speech by Mae-Wan Ho at the Bioneers conference, October 29th, 1999, and her forthcoming book, The Love of the Magician

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