MAE-WAN HO, PhD: PURSUING THE SCIENCE OF GLOBAL COHERENCE

Interview by David Riley, MD; Rollin McCraty, PhD; Suzanne Snyder • Photography by ISIS image

Mae-Wan Ho, PhD, is best known for her pioneering work on the physics of organisms and sustainable systems; she is also a critic of genetic engineering biotechnology and neo-Darwinism. She is director and cofounder of the Institute of Science in Society (www.i-sis.org.uk) and editor-in-chief and art director of its trend-setting quarterly magazine Science in Society.

She has authored or coauthored more than 170 scientific publications, more than 500 popular articles, and more than a dozen books, including The Rainbow and the Worm: The Physics of Organisms *(3rd ed, 2008);* Genetic Engineering: Dream or Nightmare? *(reprint with extended introduction, 2007);* Food Futures Now *(2008); and* Green Energies, 100% Renewables by 2050 *(2009).*

***Editor's note**: This interview was conducted by David Riley, MD, editor in chief of* Alternative Therapies in Health and Medicine (ATHM); *Rollin McCraty, PhD, director of research at the Institute of HeartMath, Boulder Creek, California; and Suzanne Snyder, managing editor of* ATHM.

***ATHM* (Ms Snyder):** Please tell us a little bit about your background and schooling.

Dr Ho: I was born in Hong Kong. I started school in Chinese and then transferred to an Italian convent school, basically an English school for girls, run by Italian nuns. I got exposed to Western ideas late-ish in life, probably when I was about 10 or 11 years old. I was lucky because I was quite good in school, and the nuns let me do whatever I liked. I didn't have to listen to them if I didn't want to. So I escaped the worst of reductionist Western education because all these ideas that didn't fit just rolled off my back. I guess that explains why I'm always at odds with whatever the conventional theory is in every field that I go into.

***ATHM* (Ms Snyder):** How long did you attend the convent school?

Dr Ho: I was there until I entered university. I read biology and then biochemistry as a doctoral candidate at Hong Kong University. And again, I learned nothing useful during the whole of my education. Maybe I exaggerate. I learned by myself of the things that I liked to learn about. After I finished university, I got a postdoctoral degree, and then I began to change fields because I didn't like the kind of research I was doing. I didn't like the ideas. I revolted against neo-Darwinism and the reductionist way of looking at things in bits.

I had gone into biochemistry because I was excited by something I heard from one of my professors who quoted Albert St Györgyi—the father of biochemistry—who said that life was interposed between two energy levels of an electron. I thought that was sheer poetry. And that made me want to know, "What is life?" That was the major question I wanted to answer.

So I went into biochemistry thinking I would find the answer there. But it was very dull because biochemistry then was about cutting up everything, grinding up everything, separating, purifying. It still is, really. Nothing really told you about what life is.

Biology was studying dead, pinned specimens. There was nothing that answered the questions, "What is this biological organization? What makes organisms tick? What is being alive?" I especially detested neo-Darwinism because it was the most mind-numbing, brainless theory that you could explain anything and everything by "selective advantage." Everything was about competition and selective advantage. It was so mind numbing.

I'd spend a lot of time criticizing neo-Darwinism until I got tired. What neo-Darwinism leaves out is the whole of chemistry, physics, and mathematics. You don't need any physiology or developmental biology if everything can be explained in terms of selective advantage and a gene for any and every character, real or imaginary.

Finally, I met some quite remarkable people and learned a lot from them and completely changed my field of research. I'm not really a biophysicist; I wrote a book called *The Physics of Organisms,* which is completely different from what people were doing in biophysics. That was how I came to be studying quantum coherence and various other things.

***ATHM* (Ms Snyder):** Did you change fields during your schooling or afterward?

Dr Ho: It was after my schooling. It was almost a complete break with my previous training. In the first year of university, we had

Opposite: Mae-Wan Ho, PhD, believes that quantum coherence is everywhere and that, applied correctly, it is the key to health and happiness.

to do everything. We had to do all sorts of chemistry, including thermodynamics. Thermodynamics was the first class in the morning. It was a huge class. I always arrived late. The lecturer spoke very quickly, very quietly, wrote things on the board with one hand and rubbed them off with the other. So I understood nothing at all.

I had to relearn all the thermodynamics, but that came later. The first person who started to influence me was Fritz Popp, a quantum physicist studying light emissions from living organisms. When I first met him, I didn't understand a single word of what he was saying, but he mentioned something called quantum coherence. I had a feeling it was very important, and I decided to find out as much as possible about it.

***ATHM* (Ms Snyder):** Who were some of your other influences?

Dr Ho: The other person whose work influenced me was Herbert Fröhlich. Fröhlich was a solid-state physicist. He was very interested in the whole idea of why organisms are, among other things, so sensitive to electromagnetic fields and microwaves of very low intensity, very weak fields. He had a theory of coherent excitations that was related to the theory of quantum coherence because he treated the organism almost like a solid-state system.

His idea was that the living cell is not like a bag of water with enzymes dissolved in dilute solutions. In fact, when you look at it, the whole thing is jammed with molecules and organelles, and it's more like it's a solid state. In such a system, if you pump it up with energy, just like a laser, you could get into coherent states. That was easier to understand. With the help of my good husband, who is a mathematician, Peter Saunders, I began to understand what Fröhlich was talking about. Then I went and worked with Fritz Popp, and I learned a lot of really deep quantum theory from him. He was a very good teacher and, in the end, I learned things from him that maybe he didn't intend to teach. I owe him a real debt. Working with him was very enlightening.

After I learned quantum theory from him, I began to go back and relearn all my thermodynamics. I had another wonderful teacher named Kenneth Denbigh. He was well known for a number of excellent textbooks on nonequilibrium thermodynamics. The most important one for me was a little book called *The Thermodynamics of the Steady State*. I was fortunate enough to be in constant communication with him—he was retired by then. He was a very generous teacher, so I ended up extending his work with his blessing. He remained my friend to the last.

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Another person who influenced me was Erwin Schrödinger, who wrote *What Is Life?* Of course, I'm not old enough to have interacted with him directly.

Those are some of the influences that led me to write my book, *The Rainbow and the Worm: The Physics of Organisms*, which was first published in 1993. That was when I first applied quantum coherence seriously to explaining living organization. The definitive theory was in the second edition, published in 1998. The first edition was more or less patterned after Schrödinger's *What Is Life?* The remarkable thing about Schrödinger's book is that he wrote it before solid-state physics, before the transistor was invented. Most people know that book because it predicted DNA as the genetic material. But that was only half of the book. The other half of the book was about coherence. That was the line that I followed. In about 1996, I suddenly had an insight into a theory of the organism—the thermodynamics of living organisms. That is more developed in the 1998 edition of the book. The book was enlarged and updated in a third edition in 2008.

When the book was first published in 1993, I said that quantum coherence was responsible for biological organization, and nobody really believed it even though I provided a combination of what appeared to me good theoretical arguments backed up by experimental evidence. Not even my best friends believed it.

Now in 2010, one of the things that most excites biologists these days is quantum coherence being involved in photosynthesis. Photosynthesis is the process whereby green plants and other

Quantum Jazz 2. Acrylics and Chinese ink on A1 paper (594 x 840 mm), Mae-Wan Ho. This is number 30 of a series Dr Ho started in May, but, she says, only the final two succeed in being quantum jazz. She describes the painting as "a symphony of colors and forms, colliding, merging, overlapping, created on the occasion, by dancing with the 'spirits' of all nature. It is improvised and spontaneous, like life itself."

organisms harvest light. They obtain energy from the sun for growing and doing all the sorts of things that constitute being alive. Using very sophisticated instrumentation, scientists have discovered that the very fast reactions involve quantum coherence. They are amazed that quantum coherence can exist and can persist for hundreds of femtoseconds. A femtosecond is 10^{-15} second. And this happens over a distance of nanometers (10^{-12}m). Scientists are very excited about that, which is sad because the whole organism is quantum coherent.

***ATHM* (Dr McCraty):** Quantum mechanics is important in explaining the biochemistry in the molecules. As you said, many scientists go on to treat the molecules like classic ball-and-stick models. But how those nonliving chemicals get magically turned into living systems is still a mystery. So you are saying that coherence is the defining quality of a living system?

Dr Ho: We discovered an imaging technique in my lab that all organisms look like liquid crystalline displays. We put these little organisms under a microscope, under the polarizing light microscope that earth scientists use to look at rock crystals. The microscope has two crossed polarizers, so the field is completely dark as no light can get through unless you have these rock crystals that are "birefringent"—that have a particular kind of crystalline order that changes the direction of light, so they appear bright and colorful. These crystals have a special atomic order. Liquid crystals do the same; they are also birefringent. They have special molecular alignments and can appear bright and colorful, too, but you need a special setting to bring that out, as the birefringence is weaker than in rock crystals, though the principle is the same.

However, in a living organism, there is nothing static there, and that was what puzzled us at the beginning: How can they look like liquid crystal displays? They're moving around all the time, so there can't be any static molecular order to give the brilliant colors. That's why I called my book *The Rainbow and the Worm: The Physics of Organisms.* The "worm" wasn't really a worm; it was a *Drosophila* larva, a little fruit fly larva that hatches out of an egg.

When we made this amazing discovery, which gave me one of the most powerful aesthetic experiences I had in my life, I was actually looking for something else. I was looking for a molecular order in the egg that is more subtle, like a pre-pattern of the body plan that eventually appears in the course of development. That

was what we were looking for. And we did find it, but it was nowhere near as exciting as the moving organism appearing like a dynamic liquid crystal display.

The explanation is that all the molecules are moving coherently together and the molecular motions are slower than the vibrations of light. So at every instant, the light senses this molecular order and therefore gives you this liquid crystal display. That really is the best evidence of the molecular coherence that exists in the whole organism. The water associated with the living organisms—some 70% by weight and 99% by count of molecules—is most important in this respect because the water is responsible for a lot of the liquid crystallinity and also the flexibility of the proteins and other macromolecules, so that they can all move coherently together.

The quantum coherent organism is not completely a theoretical exercise, though if you just apply the conventional quantum theory to organisms, it doesn't work. The conventional quantum mechanics needed to be stretched, and that's what I did in my book. The analogy is a kind of a multimode laser that is pumped up to be coherent in many different frequencies, a whole range of frequencies. If you look at the organism, the range of frequencies is just fantastic.

> IF YOU HAVE A FULLY QUANTUM COHERENT SYSTEM, YOU WILL NEVER AGE AND YOU WILL NEVER DIE. BUT WE DO AGE AND WE DO DIE. THAT'S BECAUSE OF INCOHERENCE OF VARYING DEGREES.

In my book, I say that it's like 70 doublings of the octave. I use the analogy of quantum jazz in order to express this quantum coherence that is special to the organism. It goes through many ranges of space and time scales, from the tiniest atom or subatomic particle to the whole organism and beyond. Organisms communicate with other organisms; they are attuned to natural rhythms as well, so they have circadian rhythms, annual rhythms, and so on. At the other extreme, you have very fast reactions that take place in femtoseconds, or tenths of femtoseconds, up to circa-annual rhythms.

So if you can imagine, all these rhythms are coordinated. There is evidence that they are actually coordinated over all these scales. Of course, you can never find a nonliving example of this kind. You find bits of it in solid-state systems that can become coherent in a few frequencies. You find bits of it in, say, a tuned radio. When a radio is tuned, you can receive the signal that you are attuned to. The organism is tuned to all the frequencies simultaneously.

If you look at the heartbeat, it is actually a reflection of all the frequencies in the body, which makes it appear superficially to be highly irregular. But if you analyze the heartbeat with the right mathematical tools, you can extract just the kind of multimode quantum coherence characteristic of the living organism. That's what is so fascinating.

***ATHM* (Dr McCraty):** It seems that nobody agrees on a definition of a living system yet. Do you think that coherence is going to have to be included in an accurate definition of living systems?

Dr Ho: Yes, I would define organisms as "self-organizing quantum coherent systems." So the problem also involves defining quantum coherence, especially that of organisms. At the moment, there are bits of definition that fit. Phase correlation is important for quantum coherence in general terms. For example, in the heartbeat data time series data, if you shuffle the data so the data points come in a random order, the coherence is lost on analysis because the phase correlation is destroyed.

In my book, I mention factorizability, which is a bit technical. An organism is full of activities over all time and space scales. In a fully coherent system, the activities are all correlated, yet each of these activities will appear as though they are independent of all the others. That is really counterintuitive. It is because they are so perfectly correlated that the cross-correlations are just the self-correlations multiplied together. So it is analogous to the classical situation in which the joint probabilities of two independent events are just the two independent probabilities multiplied together.

This criterion of quantum coherence comes from the work of quantum physicist Roy Glauber, who won the 2005 Nobel Prize in quantum optics. Glauber's work is among the wonderful things that Fritz Popp introduced me to.

I use the imagery of quantum jazz to put it across. Imagine a huge jazz band of musicians making music, from very small instruments to the very large, playing very fast to very slow, with a musical range of 70 octaves. They are improvising from moment to moment, spontaneously and freely and yet keeping in tune and in step with the whole. That is the ultimate quantum coherence. One can have different degrees (orders) of quantum coherence. The fully quantum coherent state would be quantum coherence of *n* orders, *n* being a very large number. This state is only reached rarely, perhaps once or twice in a lifetime for some of us or maybe

not at all. You get an inkling of it when you have an aesthetic experience, a very special aesthetic experience, like one I had when first encountering the rainbow worm. Some people would call it a mystical experience. I'm not a mystic or a religious person, but I do love art. I do art as much as I do science and in much the same way. That's what makes life fulfilling for me.

You can have lower degrees of coherence than what I just described—the workaday coherence that keeps life ticking over. If you have a fully quantum coherent system, you will never age and you will never die. But we do age and we do die. That's because of incoherence of varying degrees. In my book, I suggest that time is really the accumulation of incoherence.

When you accumulate incoherence, you age. So I think a happy coherent person ages more slowly than someone full of angst and striving. It's fascinating to think about that. I'm not saying that quantum theory is the be all and end all, the answer to everything. But it gives you an insight into how to think about these things. Conventional quantum theory isn't enough. Quantum coherence has practical consequences. Please explore it. Please do something with it because it will change our whole way we regard health and disease. That's what's missing.

I have no doubt that at least some of the more esoteric things people ascribe to quantum effects are real, such as instantaneous communication at a distance, remote healing, etc. But we can't push the boundaries from the very conventional toward quantum coherence of the organism to complete quantum coherence of the universe. I believe the universe is quantum coherent. Quantum coherence is everywhere. And if we know how to tune into it, we see it. If we ignore it, if we're very reductionist and mechanical in our thinking and in what we do, we'll miss it.

***ATHM* (Dr McCraty):** I completely agree. From a very simple perspective, when we measure coherence in the rhythms of the biological system or the human being, there are the energetic parts, the things that we can't measure or touch—things like our thoughts and emotions, for example. I think of those as energetic systems but not in an esoteric way. They're the things we can't measure. But as we become more emotionally incoherent, more angry and irritated for instance, that's instantly reflected in an incoherence in the rhythmic activity of the different systems in the body. I think that parallels very well with what you were saying: Accumulating incoherence ages the system.

Dr Ho: That's right. The heart is so important. It coordinates the activities, but more importantly, it intercommunicates with everything.

***ATHM* (Dr McCraty):** Right. And is affected by everything.

Dr Ho: It is like a symphony. I'm a Taoist at heart. And quantum coherence and Taoism are one because coherent action is like effortless action. Once I found this physics of organisms, I never wanted to leave it because I realized that I needed to find my way back to reclaiming my complete self.

Western education tends to divide you up. It divides you up into the observer and the observed, the controller and the controlled. God knows what else. Life isn't like that. Life is spontaneous and free, and everything works by intercommunication. It's a perfect social anarchy because each player is as much in control as he or she is sensitive and responsive. That's the ideal of the happy person, of the healthy person.

***ATHM* (Dr McCraty):** In an article I wrote for this issue, I attempted to extend our ideas of coherence to the social level, which we're just starting to talk about. Most people have been to a concert where something magical happened, or a sporting event where a team gets into a certain kind of a flow where the players are acting as one, and it uplifts everybody.

Dr Ho: And when you've got a group of people playing music together and they get into a coherent state, it's just so beautiful. It is just the most beautiful thing. You can feel it in the audience. I'm not a musician, but I can feel how happy the musicians are when they are in that state.

***ATHM* (Dr Riley):** Is sustainability a characteristic of coherence?

Dr Ho: Yes. If you look at the thermodynamics of a sustainable system, it's actually based on this zero entropy ideal. In the quantum coherent system, because all the activities are linked together, are correlated, the entropy is zero; the system has effectively a single degree of freedom.

***ATHM* (Dr Riley):** So increasing entropy is also characteristic of incoherence.

Dr Ho: Yes. If you have an ideal sustainable system, it is a circular economy. To express it thermodynamically, if you have a closed circle, then you don't accumulate or generate entropy. Of course, the organism is an open system, and what you find is that if it doesn't accumulate entropy inside and the entropy, the entropy must be exported outside, but even the entropy exported—the waste—is minimal. That is the ideal of sustainability, and it is approached by natural ecosystems that last for thousands of years. If we want to recreate it, then we learn to do it nature's way, nature's circular economy, which is why recycling makes sense.

***ATHM* (Dr Riley):** So then our current spasms of financial crises would be a reflection of social incoherence?

Dr Ho: It's interesting: people say, "Energy is just like money." In fact, that is the greatest fallacy. In fact, the coherent system, the sustainable system, works by goodwill and by fair exchanges. It works by fair trade—you have to compensate realistically for the resources. You've got to make full compensation of resources. If you pay too little, you make people work far harder and exploit the natural resources more, and therefore you deplete your environment. And because you depend on your environment for

input, you are now poorer.

If you generate too much money, what happens? This is more like entropy because once again, you inflate artificially the buying power of some people, and they tend to consume far too much. So fair exchange is like energy. But if unfair exchange is what we indulge in, especially in the financial market, that's more like entropy, sheer entropy. That's why it tends to devastate the natural ecosystem and make everyone in effect poorer as a result.

If you look at the conventional system, because it's based on infinite growth, it doesn't close the cycle. It's like a hurricane. It swallows up everything in its path and it lays waste, and that's why it's a boom and bust, which is inherent to the system. There is more information about this on the Institute of Science in Society website (www.i-sis.org.uk).

***ATHM* (Ms Snyder):** What are you working on now?

Dr Ho: I'm working on far too many things, among which I'm trying to paint seriously. We publish a magazine at the Institute of Science in Society in which we promote both independent art and science. We are engaged in numerous campaigns to try and persuade politicians to be sustainable, not to have genetically modified foods and things like that. Maybe you should ask me what I'm not working on!

***ATHM* (Ms Snyder):** In one of your books, you say, "Science is a quest for the most intimate understanding of nature. It is not an industry set up for the purpose of validating existing theories and indoctrinating students in the correct ideologies." Based on that, do you think science is moving in the right direction?

Dr Ho: Some of it is moving in the right direction, which is why I'm so keen to keep looking at the literature to see if researchers are onto quantum coherence yet, for example. There is a lot of research on water, and I mentioned some research in photosynthesis. They're discovering, slowly, quantum coherence in living systems. In physics, quantum optics is moving in a very interesting direction as well.

Quantum computing and high-temperature super conductivity—these things are threatening to change biology. Biology is the most mechanistic still. Medicine is the worst. It's way behind. I feel very strongly about all these drugs that are not good for us. I spend quite a lot of time protecting my husband from his doctors, stopping them from giving him more drugs for his ailments. These drugs cause more side effects than anything else because medicine is still based on the same mechanistic idea.

Molecular genetics has made it worse. But even genetics is pushing in this organic, non-mechanistic direction. I wrote a book called *Living with the Fluid Genome* some time ago. It dealt with the area of why genetic engineering is so bad because it doesn't realize that the quantum coherence, this wholeness in the living organism, is in itself directing a natural genetic engineering that you can get just an inkling of in the fluid genome. The genome responds to the environment. Some responses can result in changing the genes themselves. And now, ironically, this very mechanistic push into molecular genetics is uncovering a lot more of the fluid genome.

***ATHM* (Dr Riley):** Would you say that some of the ideas that are coming out of the area of genomics validate the principle of coherence?

Dr Ho: Yes, and they don't know how to handle it. The "inheritance of acquired characters" was a hypothesis put forward by, among others, French naturalist Jean-Baptiste Lamarck. To be called a Lamarckian or a neo-Lamarckian was a real insult. I was a neo-Lamarckian back in the 1980s. Now if you look at the molecular mechanism, there is no clearer example of Lamarckism at work. It really is the inheritance of acquired characters. Experience can mark and change genes, and these influences can be passed on to the next generation. This is all coming out of the molecular genetics research, genomics. We call it epigenomics now.

***ATHM* (Dr Riley):** I would like to go back to something you said earlier. You talked about the reductionism in biology. To me, medicine is much worse. Would you agree that looking at things from a systems biology approach, rather than just a reductionism of medicine, is moving in that direction?

Dr Ho: It depends on what you call systems biology because, it seems to me, to some people "systems biology" is to put everything on a computer and hope that it makes sense. Some useful information came out of analyzing the genome, but they still fall very, very short of making sense, and it's a lot of information in search of a systems theory.

Current medical thinking is to define diseases by molecules. You have single molecule diseases; you have single molecule interventions. In fact, there are a lot of misdiagnoses, a lot of ignoring the whole system. There was so much fanfare, so much hype with gene therapy. And frankly, they've caused more grief than benefit.

You can't just push a molecule into a system because the molecules are acting in an entire network, and they've got to change according to the whole. They've got to do quantum jazz with the whole organism, with all the other molecules, and with the whole system at every single location in the body. For example, in your body, you've got trillions, tens of trillions of cells. And any single cell in your body is different at every moment. How can you say that you can cure diseases by focusing on a single molecule that you put under control of a viral promoter that makes it overexpress in every cell, all of the time?

Harmful side effects are getting worse with these so-called biologicals, biological medicines that they are pushing onto the market, which is why I said I've been spending a lot of time protecting my husband from his doctors.

***ATHM* (Dr Riley):** Can you give us an example of the biological medicines you're referring to?

Dr Ho: There are quite a number of them. And the worst ones are the antibodies. The example of these was the London drug trial catastrophe in 2006. It involved six young healthy volunteers in

London, United Kingdom, who became violently ill after being injected with a trial drug that was supposed to fight autoimmune disease and leukemia. We reported the incident thoroughly in our magazine, *Science in Society*. All six suffered multiple organ failure and were admitted to intensive care. The Medicines and Healthcare products Regulatory Agency, which gave approval for the trial, immediately withdrew authorization, and an international warning went out to prevent the drug from being tested abroad. The drug, TGN1412, was a monoclonal antibody. You can get more details at http://www.i-sis.org.uk/LDTC.php.

The names of the drugs bear no direct connection to what they really are, so you've got to look at the drug, and then you've got to figure out, "Is it a protein? Is it a monoclonal antibody? Or is it something else?" Another example is the recent swine flu vaccines: practically all are potentially dangerous, more dangerous than the swine flu itself.

***ATHM* (Dr McCraty):** How do you describe or define coherence for the layperson in a way that doesn't box it into the idea of cross-coherence and that embraces coherence in the global coherence context, whether it's at the level of the human or the human interacting within the outer system or even within the cosmos?

Dr Ho: I would describe it in terms of quantum jazz, which everyone can understand. What you're detecting in cross-correlations is a kind of coherence, but it's not the perfect quantum coherence. We haven't got a complete theory, at least not a complete, formal theory of quantum coherence of the organism. We have good theories of quantum coherence of lasers or of solid-state systems or of nonliving systems. We have very good theories of that, but we haven't got a really formal theory of the organism that you can write down in an equation. Maybe we never will. I don't know. But that's where we are.

***ATHM* (Dr McCraty):** When you were talking about the work in photosynthesis, you mentioned that the scientists are all excited about coherence over a few femtoseconds, but the measurements that you've done in the larvae are showing global coherence sustained over minutes.

Dr Ho: I'm sure if we put you under a polarizing light microscope, you would be liquid crystalline as well.

***ATHM* (Dr McCraty):** Well, right there is an example of coherence. It's sustained over minutes to hours.

Dr Ho: Long coherence times mean nothing. By the way, Fritz Popp is still involved in light emission biophoton research. Some of my friends in Catania whom I also work with, including Franco Musumeci, and I all met at Fritz Popp's lab. We found a lot of evidence of long-range coherence, as described in my book, but it tends to be dismissed because people don't understand it and because you can't write down an equation on it. But I have no doubt that life is quantum coherent. Organisms are quantum jazz players, dancing life into being.