Opening Doors to a Quantum Theory of Life, Part 1: Properties of Life at the Quantum Level

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Abstract: The idea that the key to life might be a quantum process is not new. Niels Bohr, Erwin Schrödinger, and Werner Heisenberg found signs of life at the quantum level. What they saw was useful, but not enough to solve the mystery of how life works. Two recent interpretations of quantum mechanics add new pieces to the puzzle: Quantum states act the same as what biologists call "anticipation" when the future possibilities of *superposition* states influence the outcome. And quantum *wave function collapse* acts the same way as what biologists call "purposeful actions" when a choice is made.

This paper, the first in the series, "Opening Doors to a Quantum Theory of Life" (ODQTL), explores in detail the above two properties that are traditionally seen by biologists as being unique to life. In fact, many surprising traits of life *are present* at the quantum level. The idea that quanta might be alive is explored and shown to be a valid interpretation.

A detailed theory of life is presented in Part 2 of this ODQTL series. It is published in this same issue of *Integral Review* (Marman, 2023b). The new theory explains how cellular life might have emerged from quantum processes. It offers a Catalyst-First Hypothesis and shows why catalysts might be the real drivers of life, not metabolism, RNA, or accidents such as lightning striking primordial soup.

The new theory that emerges from this series of papers proposes that life is not based on the right combination of ingredients; it is a *mutually responsive relationship* between a life form and its habitat. We cannot take this relationship apart to study how life works because taking it apart kills the process of life. Quantum theory can explain this irreducible property as an entangled state, but new interpretations of quantum mechanics are needed to show why quantum principles *must* also be actively involved in relationships between organisms. This insight suggests that, when trying to understand life, *context* is more important than *content*. As a result, the science of quantum biology can expand to include interactions between organisms, opening doors that take us beyond quantum mechanics and chemistry, and perhaps even beyond biology to include psychology, as Heisenberg predicted.

Keywords: Consciousness, entanglement, mind-body problem, quantum formalism, quantum measurement problem, panpsychism, superpositions, wave collapse.

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Introduction

Biologists have a hard problem: We have no explanation for how life works. We see living organisms all around us every day: flowers, trees, birds, fish, bacteria, and human beings. But what is it that makes them alive? What is it that allows us to live?

For hundreds of years, scientists have searched for answers to these questions. Discoveries about the genome, neural networks, epigenetics, microbiology, the functioning of organs, and the complex roles of enzymes and hormones have enriched our understanding of biology in countless ways; yet the core principles of life remain a mystery. When it comes to explaining functions, mechanisms, and reactions, the scientific process excels; still, for some reason, the key to life has eluded science. It is right before our eyes, but we can't see it because we have not yet found the right lens.

On the other hand, we do understand how machines work. We have learned that everything in a machine can be explained through *cause and effect*, where each component is driven by forces. We also realize that, when we push a cart up a hill, we feel the force of gravity opposing us. We know that the moment we let the cart go, gravity will have its way and send the cart crashing back down the hill. We have a lens that sees cause and effect clearly. But, for some reason, this lens does not help us grasp how *life* works.

Look at the following unsolved problems. When reading these examples, notice how mysterious it feels to miss something that we face every day. Why is it that we cannot see what it is that makes living creatures different from machines?

1. It is easy to disassemble a machine to see how it works and then put it back together without losing its functionality. However, creatures work in a unique way that is not found in even the most sophisticated machines: Taking apart a living organism to see how it "works" kills it, kills the process of life. This trait of living creatures seems simple, but no one can explain it with currently known laws of classical physics or chemistry.

2. Living organisms also show signs of choosing to act for a purpose, and they have the ability to anticipate what will happen in the future in response to what they might do. Machines, on the other hand, are only driven by forces that act in response to the present moment. Therefore, it makes no sense to say that machines anticipate or have the ability to act for a purpose.

3. Cells in multicellular animals, plants, and fungi form working relationships that are so closely aligned with each other that they are able to act as single individuals. And each creature is able to originate behavior *from within*. As a result, creatures can act in ways that are unpredictable to outsiders, making it impossible to control living things fully. On the other hand, the way components behave in machines is easily explained because we have a lens that shows us how parts interact with each other. In fact, machines are so predictable that users can control them fully *from the outside*.

4. The differences between living and dead organisms suggest that getting the assembly of cells exactly right is not a required element of life because the arrangement of cells does not change in a significant way after death. What changes is what those cells do. In fact, when alive, new cells reproduce spontaneously to replace damaged cells and to heal organs, correcting problems through a new arrangement of cells. However, when it comes to machines, the precise assembly of components is crucial.

5. Life forms find ways to sustain their flow of life through receptive-responsive relationships between all of their organs. But this complex relationship cannot be reduced to cause-and-effect interactions alone. And analyzing the flow of energy into and out of chemical reactions in cells does not help explain how life sustains itself for such long periods of time. It takes more than just receiving and using energy – even cell phones can use and store energy.

These puzzles describe traits of life that we face every day. They are familiar. But we cannot explain them using the tools that biology, chemistry, and classical physics offer today, leaving us with no answer to the question of what makes living creatures different from machines. This is *the hard problem of biology*. Finding a solution that is simple enough to show us clearly and intuitively how life might work – that is the goal of this ODQTL series of papers. This paper is Part 1.

As we will see below, quantum physicists found valuable clues about life after running into similar problems at the quantum level. In fact, the similarities between the behavior of quanta and living organisms were so strong that some early founders of quantum mechanics felt convinced they were on the verge of solving the mystery of life. Instead, they ended up hitting the same wall as biologists, concluding that new science is needed to explain how life works.

The wall physicists hit shows that they lacked the right lens to make sense of life. A lens of perception is not a belief or a system of ideas or models to help us think. Lenses go much deeper. They emerge naturally from our experiences and our work. Psychologists also call them "schemas" and "perceptual sets." They shape our perceptions and our understanding. (Marman, 2016)

The discovery of quantum mechanics pulled the rug out from under the main ideas of classical physics, such as cause-and-effect, forces, matter, space, and time. That foundation is now gone in quantum theory, with no clear understanding about what is truly fundamental.

Biologists face a similar problem; they do not know what is fundamental for life. They have plenty of beliefs and models for how organs, reproduction, embryo development, and neural networks work, but no deeply satisfying way to make sense of what life itself is. I believe that this may be the same wall physicists hit because they appear to be deeply connected.

Two relatively recent interpretations of quantum mechanics now open doors to understanding life. Integral Review published the most recent, and least well-known, of these interpretations in 2018: "The Lenses-of-Perception Interpretation of Quantum Mechanics." Known as the LoP Interpretation, it distinguishes itself from other interpretations in two main ways. First, it is the only interpretation founded on a theory of principles. All other interpretations of quantum mechanics are based on functional model theories that are sometimes called "constitutive theories." (Marman, 2018)

Lee Smolin (2017) writes about trying to solve the problems that have dogged quantum mechanics for a century. He wonders what physicists might be doing wrong and concludes that one of the things we might need to do is to spend more time looking for new underlying principles.

> Here is another way in which I suspect we have been off track. Einstein spoke of two kinds of theories, constitutive theories and principle theories. Constitutive theories posit

> what the world is made of; they are theories that describe particular phenomena, particular forces or particles…. Principle theories set out general principles whose universality requires that every particle and force in nature satisfies them….
>
> Einstein taught us that we deepen our understanding of nature when we discover new principles. The theories come after the principles…. Perhaps we should heed Einstein's advice and look instead to discover new principles. (p. 230)

The LoP Interpretation is founded on a set of principles that lead to an intuitive explanation for what it is that makes quantum behavior seem so irrational. All of these principles are derived from one simple postulate: Fundamental quantum particles are sentient. However, sentience by itself is not what makes the behavior of quanta seem so bizarre. No, the real cause comes from the baffling nature of relationships between sentient agents because they are so unpredictable.

This postulate sounds crazy, as it should, because all interpretations of quantum mechanics have an element that must be fundamentally weird. Nothing else can produce the results needed. Niels Bohr (2023) put it this way: "We are all agreed that your theory is crazy. The question that divides us is whether it is crazy enough to have a chance of being correct."

Fortunately, the assumption that quanta are sentient is not just crazy, it also leads to a prediction that is both surprising and unavoidable: If sentience is the source of the bizarre relational behavior between quanta, then quantum properties *must also exist in the receptive-responsive relationships between organisms* – because they are sentient as well. This suggests that the wall hit by quantum physicists might relate directly to the hard problem of biology.

Because it goes against conventional wisdom to find quantum behavior at the macroscopic level of organisms, it is easy to test the theory. We *must* be able to find all of the same quantum effects, such as entanglement, wave/particle duality, superpositions, wave function collapse, uncertainty, etc., in *all of the relationships* between living organisms. Not just a few of these bizarre quantum traits, *all of them*, must exist in the relational behavior of life forms. And *they must always exist* in all relationships between organisms. This is the second way that LoP Interpretation distinguishes itself. And, as I will show, this prediction – as surprising as it sounds – holds up under analysis.

This radically alters the scope of the new emerging field of quantum biology. Previous research in this field has focused *only* on the roles that quantum effects play in organisms *at the atomic level*. This paper proposes that quantum interactions also exist between life forms in ways that play crucial roles in their lives, creating true quantum effects that go far beyond the atomic-level. This turns out to be an important key needed in unlocking the mystery of life.

As theoretical physicist Carlo Rovelli (2008) says, a principle-based theory offers advantages:

> Quantum mechanics will cease to look puzzling only when we will be able to derive the formalism of the theory from a set of simple physical assertions ('postulates,' and 'principles') about the world. (p. 2)

This is exactly the approach taken by the LoP Interpretation. However, basing a theory of life on principles alone is not enough, especially when it comes to testing the theory. Functional models are also needed.

For example, as Rovelli (2008, p. 2) points out, both of Einstein's theories of relativity are based on principles. In his Special Theory, one of the founding principles is that the speed of light looks the same to all observers. In his General Theory, Einstein introduces the principle that the force of gravity is equivalent to inertia. These principles lead to surprising predictions that can be tested, such as the relativistic dilation of time, and the bending of light rays from distant stars when they travel through gravitational fields. However, Einstein also needed functional models to determine exactly how relativistic effects behave.

Functional models are familiar to physicists because they describe *how* things work, and they give us mathematical terms that can be tested in convincing ways. Quantum theory is founded on functional models. Fortunately, there is another relatively recent model-based interpretation that also shows that the theory of life presented in this series is consistent with quantum formalism. In fact, it allows us to derive quantum formalism from principles.

The "Relativistic Transactional Interpretation of Quantum Mechanics," (RTI), first published by Ruth Kastner in 2013, and updated in 2022, offers a model that shows exactly what happens during the wave function collapse process (Kastner, 2013). This provides a detailed model that aligns with LoP principles. With the *functional models* from RTI, and the *principles* from LoP Interpretation, we can open doors to new ways of understanding the process of life.

Life as a Quantum Process

The idea that the key to life might be a quantum process is not new. Niels Bohr, Erwin Schrödinger, and Werner Heisenberg found enticing signs of life at the quantum level. They saw enough to write about it but not enough to solve life's mystery. With the above two interpretations, we can now add some crucial elements that they missed.

For example, I will show that quantum states display properties of "anticipation" when future *possibilities* have an influence on quantum states. This is a strange property of superposition states. And a quantum wave function collapse occurs only after a *choice* is made in the same way as "purposeful actions."

I'll show that these traits of life *do* exist at the quantum level. This paints a possible new picture about the origin of cellular life, which I explore in Part 2 of this series (Marman, 2023b). The new theory that emerges suggests that life is not based on a combination of ingredients; it is a *mutually responsive relationship* between a life form and its habitat. This means that life does not belong to us as *individuals* alone because our life is a shared relationship state between us and the world we depend upon for sustenance.

Discovering that these relationships of life between organisms also exist between quantum particles may offer us a new way to solve problems that have been standing in our way. Scientists may have been looking at this backwards. Perhaps we can learn more about quantum states if we start with a biologist's perspective, rather than relying only on the physicists' way of seeing these traits. For example, after seeing the strange behavior of quanta, a biologist might ask: Is it possible that quantum particles possess some form of sentience? Could they be "alive"?

Niels Bohr (1958a) made an interesting observation that relates to these questions. He said that it is impossible to distinguish "subject" from object (p. 22). In other words, we never see sentient agents directly. When we study organisms, we only see the actions of their bodies.

If this is true for organisms, and if quanta are also sentient, then we face the same situation at the quantum level. This offers an explanation for one of the strangest facts of quantum theory – fundamental particles, like electrons and quarks, are represented mathematically as dimensionless points. Particles are no longer seen as bits of matter for this and other reasons. Then, what are they? This makes sense if particles are sentient agents because it is impossible to see or measure agents directly. Thus, sentient agents occupy no space by themselves. (More about this later.)

There are many implications that come from opening these doors to a quantum theory of life:

- Using a biologist's perspective offers a deeper understanding of quantum states, and this allows us to propose a comprehensive solution to the quantum measurement problem that also makes intuitive sense, as I will show later in this paper.

- Only after we have a scientific explanation of what life is and how it works can we propose a theory about the origin of life. It then becomes clear that the most important aspect of life is this: That each cell influences the chemical reactions taking place within its body. This means chemical reactions by themselves are no longer the only driving force. There must be "top-down" influences as well. And this process is needed to sustain organisms in a state that is far from equilibrium with its environment.

- A quantum theory of life can offer a clear picture for how top-down influences might work, not only at the levels of organisms, but at the quantum level as well, since this is fundamentally a quantum process. This explanation is presented in Part 2 of this series (Marman, 2023b, sections 2-4).

- Once we see how this might work, it becomes clear that this is not about metabolic functions, RNA molecules, or lightning striking primordial soup. None of these origin of life hypotheses can explain top-down influences. But we find what we are looking for with catalysts. The process of catalysis may be the true driver behind the emergence of cellular life. This is explained in Part 2 (section 9). An experiment that supports the top-down influence of catalysts is presented in the Addendum of Part 2.

- Without an explanation for what life is, we have no way of determining when *human life* starts. Once we see how birth and death works, it becomes clear that human life could never begin with conception. In fact, conception is not even the origin of the life of a new cell, it is only a transformation, like the change that takes place in a cocoon that produces a butterfly. Transformation is a change, not a beginning to life. Instead, ancient traditions may be correct that life truly starts when first-person perception enters; just before the first breath with humans and animals, and just before the shell breaks open from the inside, with birds, reptiles, and plants. This is explored in Part 2 (section 10).

This gives a glimpse into the significance of finding a new lens that corrects our perception by opening doors to understanding how life works. However, this is new science; so, more validation and testing are needed, and interesting challenges remain.

Closing the gap between quantum mechanics and biology makes it possible to see that life may have emerged from quantum processes. This theory raises the possibility that the "mechanisms" of Charles Darwin's theory of evolution may work as "non-local quantum effects" that do not act *in* present time, but *across* time and generations. These new possibilities, and many more, will be presented in future papers. In the first two papers, Part 1 and Part 2, three crucial functions are presented, starting with four founding principles, leading to a quantum theory of life.

If the theory of quantum biology proposed in this series of papers is correct, then we will never be able to turn biology and "soft" sciences (such as psychology and sociology) into "hard" sciences (like classical physics and chemistry) because too many quantum effects are involved when organisms form relationships with each other. In other words, classical physics and chemistry are "hard" only because they deal with things that are not sentient, such as machines and chemical reactions that only absorb or dissipate energy.

Understanding quantum mechanics in an intuitive way is so difficult that *most* physicists have given up trying. Quantum formalism allows them to use the principles of quantum mechanics perfectly without knowing *why* the quantum world is so strange. As a result, new physics students are often instructed to stop asking *why* questions. They are told to just learn the math.

Biologists have also gotten used to the idea that we do not know how life works. But they are far less willing to give up so completely on the desire to explain life. Life is too much a part of the behavior of the organisms they study. And they see displays of life all around every day. The hope of solving this mystery remains alive in most biologists. This is another case where physicists might learn something from biologists.

Discussions about complexity, replicating chemistry, metabolic pathways, computer algorithms and self-ordering systems miss the point. Complex mechanisms and chemical reactions are not enough to explain life. Even random events do not help. Life needs the ability to choose in a way that offers a top-down influence over our cells and organs. This is how we find food and avoid threats. Genes and chemistry cannot do that on their own.

It is clear that most origin-of-life theories avoid the hard problem of biology. None of them explain how an "abiotic" world could leap from cause-and-effect interactions to creatures that anticipate, postpone death, flee dangerous situations, and form receptive-responsive relationships. We have been missing something important: an explanation for how life works. The new theory proposed in this series of papers suggests that we should move on from studying how outside forces drive change through mechanisms to a better understanding of the unpredictable and irreducible aspects of relationships between organisms and quanta.

We will begin by turning to the first clues of life found by discoverers of the quantum world.

1. Signs of Life in the Quantum World

If classical physics and modern chemistry cannot solve the hard problem of life, what about quantum mechanics? A number of similarities between the enigmatic nature of living things and the bizarre behavior of quanta suggest that there might be a relationship. In fact, three founding fathers of quantum physics felt these resemblances between organisms and the quantum principles they discovered were so compelling that they were close to solving life's greatest mystery.

> In general, the creators of The New Quantum Theory believed they had at last penetrated the innermost secrets of all matter. I have been told, by numerous participants and

> observers of these developments, of the pervasive expectation that the "secrets of life" would imminently tumble forth as corollaries of this work. (Rosen, 2000, pp. 8-9)

That never happened. Instead, quantum mechanics ran into its own problems that have still not been resolved after a hundred years. However, a number of similarities between the enigmatic nature of quanta and organisms were so strong that they jumped out at these physicists exploring the subatomic world. They offered a number of fascinating observations. This is worth reviewing.

1.1. Niels Bohr

Niels Bohr (1958b) first spoke about this at length in 1932, in a lecture entitled "Light and Life." He started off describing the quantum properties of light and why they cannot be explained by cause and effect. Countless experiments have shown that, to grasp a complete picture of light, we need to accept both its wave-like nature and its particle-like nature, even though these two properties are distinctly different from each other. Bohr called these properties "complementary" because both aspects work together; and yet, we can only measure one property at a time. (p. 5)

There is no way to run experiments that reveal how the wave-like nature and particle-like nature of light work together. According to Bohr, "this very situation forces us to renounce a complete causal account of the light phenomena and to be content with probability laws" that are valid only in a statistical sense. (p. 5)

To illustrate, he describes what happens when a single photon – a quantum of light – is absorbed by an atom. It causes the atom to shift from one quantum energy state to another. Any attempt to observe the transition is impossible because "measuring instruments…would completely disturb the very energy balance we set out to investigate." (pp. 6-7)

In other words, there is no objective way to see the transition when an atom changes from one state to another. The reason for this, according to the discoveries made by Bohr in 1913, is that the transition appears to be discontinuous. It makes a quantum leap, not a gradual transition. It shifts from one state to another without passing through intermediate stages.

Newtonian physics has a problem with instantaneous shifts: They are impossible. Forces should only cause objects to accelerate. This produces gradually increased changes. Only an infinite force could create a discontinuous shift. This is why Bohr concluded that the "quantum of action" is a basic fact that cannot be explained by cause-effect reactions.

Bohr then shows the similarity between this strange property of light and the problem of life. He says that we will kill an animal if we

> carry the investigation of its organs so far that we could tell the part played by the single atoms in vital functions. In every experiment on living organisms there must remain some uncertainty… [that hides] its ultimate secrets from us. On this view, the very existence of life must in biology be considered as an elementary fact, just as in atomic physics the existence of the quantum of action has to be taken as a basic fact.... Indeed, the essential non-analyzability of atomic stability…presents a close analogy to the impossibility of a physical or chemical explanation of the peculiar functions characteristic of life. (p. 9)

Bohr is saying that our inability to take living creatures apart to see what makes them alive is similar to a quantum leap because we cannot take the leap apart to analyze it. The inner workings are hidden from outsider observation. This is why they cannot be reduced to cause-effect reactions. Perhaps the secret of life cannot be observed objectively for the same reason.

In other words, Bohr is suggesting that we see the same kind of irreducible quality with life that we find in atoms. There is no way to break apart atoms or living organisms to see how they work without destroying the phenomenon we are trying to observe. This might explain why classical physics and chemistry cannot explain the behavior that makes life special because a quantum approach is needed.

Unfortunately, there is a problem that overshadows Bohr's argument: Paul Hoyningen-Huene (1994) explains in his critique that even if the flow of life and chemical reactions in organisms are complementary, meaning that we cannot take apart the elements to study them without losing what we are trying to study, this does not prove that life is irreducible. First, someone needs to explain why the process of life in organisms is distinctly different from the chemical reactions taking place. Second, someone must show why life cannot be reduced to reactions. Without these two steps, the apparent irreducibility of life proves nothing. (pp. 252-253) Hoyningen-Huene makes good points.

Bohr saw that one of the biggest problems with trying to understand life is that it cannot be reduced, while chemical reactions and mechanical functions can. This is what makes the hard problem of biology so difficult. Bohr shows how similar this is to the complementary properties of quanta. But his insight falls short because he offers no explanation for what makes quantum states irreducible. Why is it impossible to measure both the wave-like and particle-like nature of light at the same time? Why does measuring one make the other uncertain? Bohr not only admits that he cannot answer these questions; he suggests that they may be unanswerable.

This similarity between the irreducible energy states of atoms and organisms offers a tantalizing clue. However, even though Bohr shows that the quantum states of atoms cannot be reduced to cause-and-effect interactions, he gives us no good reason why this irreducible state exists at the quantum level or why this should apply to living creatures. If the two are not directly related, then we are left with an intriguing resemblance that may be a mere coincidence. This is not compelling.

Making the matter worse, Bohr (1958b) points out key differences between atoms and biology. For example, he says that quantum mechanics describes the workings of matter in its simplest forms, while biology studies the most complex systems in the world (p. 9). In other words, biological organisms and quanta are at opposite ends of the spectrum. I show in Part 2 (Marman, 2023b) that Bohr was wrong about this difference because we find the same kind of complexities in both atoms and organisms, and the sources of these complexities may turn out to be remarkably simple.

Bohr muddies the waters even further when he goes on to say that

> we cannot even tell which particular atoms really belong to a living organism, since any vital function is accompanied by an exchange of material through which atoms are constantly taken up into and expelled from the organization which constitutes the living being. (p. 10)

In other words, there is no way to clearly distinguish which atoms belong to an organism and which belong to the environment because organisms continually exchange atoms with the habitat where they live. This is an interesting point, and he goes on to say that this "exchange of matter extends to all parts of a living organism." (p. 10) He is right. Our cells are continually dying off and being replaced. Even proteins, the building blocks of cells, are replenished continually.

If we remove a living animal from the air it breathes, from the water and food it needs, it will die. This means that it is not just the complementary relationships taking place inside of a living organism that cannot be taken apart. We also cannot take an organism out of its habitat. Thus, the process of life is irreducibly complex both inside and outside of creatures that are alive.

This is a fascinating observation, but Bohr then goes on to say that this inability to separate organisms from the world they live in is different from atoms. In fact, he believes that this goes to the heart of the difference between living and inert matter. Atoms exist independently, he claims, but organisms do not. And reactions between atoms can be studied one by one, he says, while relationships between life forms and their habitats are irreducible.

It is easy to see the point that Bohr is making, but, as I will show later, he is wrong about atoms. Yes, it is true that the electromagnetic interactions between atoms can be taken apart and studied independently. But not all atomic reactions can be reduced to electrical interactions. For example, interactions between atoms cannot be reduced when the strong force is involved (Part 2, Marman, 2023b, p. 130).

Look at the reactions taking place in stars when hydrogen atoms fuse together to form helium, releasing huge amounts of light and energy. During this process of fusion, protons change the atoms they belong to. It is impossible to determine if a proton belongs to one atom or another during fusion. And any attempt to measure the proton would interfere with the process of fusion.

Bohr was equally wrong about organisms. Many interactions with organisms *are* reducible. For example, take a person interacting with the pedals of a bike. Pedaling can be reduced to discrete forces and interactions in the same way we study reactions between atoms. And the way birds flap their wings to fly can be analyzed as a cause-and-effect process. In other words, when organisms act as individuals, they appear to be distinct from each other, but the process of life is built on a relationship with the environment that cannot be taken apart. More about this in Part 2 (Marman, 2023b).

Bohr points out another important distinction between the flow of life and physical reactions: Self-preservation requires directed efforts by organisms. This means searching for food and fleeing dangers. Therefore, it makes sense to use the terms "purposes" and "goals" when referring to the actions made by creatures. But it would be wrong to assert a sense of purpose or intention behind the actions of machines (p. 10). The behavior of living things can't be reduced to only outside forces. Their actions often originate from within them. They make choices. In this paper I will show that, surprisingly, quantum particles also display similar traits of free will.

Bohr asserts that free will in organisms should be accepted as fundamentally real and should not be treated as a cause-and-effect process. He says that we will never understand free will from the standpoint of causation because there is no objective way to distinguish the "subject" who initiates an act from the actions of their body (p. 11, see also pp. 21-22, 78, and 93). As I show in Part 2 (Marman, 2023b, p. 137), Bohr is right about this fascinating insight, and it is this inability of outside observers to distinguish subjects (that are sentient agents) from their bodies that makes it so difficult to understand the meaning of birth and death. This issue needs to be resolved if we want a complete theory of life. And remember, if quanta are sentient agents, then we face the same challenge at the quantum level as well.

1.2. Erwin Schrödinger

In 1943, Erwin Schrödinger gave a series of lectures entitled "What is Life? The Physical Aspect of the Living Cell." The book soon became famous and went on to influence a number of leading biologists. For example, both Francis Crick and James Watson claim that it inspired them in their search for the double-helix model of DNA (Schrödinger, 2001, see link).

According to Schrödinger (2001), the purpose of his book is "to convey one idea only":

> How can the events in space and time which take place within the spatial boundary of a living organism be accounted for by physics and chemistry?
>
> The preliminary answer which this little book will endeavor to expound and establish can be summarized as follows:
>
> The obvious inability of present-day physics and chemistry to account for such events is no reason at all for doubting that they can be accounted for by those sciences. (pp. 3-4)

Schrödinger goes to the heart of the hard problem of biology. He addresses the most difficult challenges. He says that our current understanding of physics and chemistry cannot explain living organisms, but he goes on to argue that there are good reasons to think that one day physics and chemistry will solve this mystery. He says this to convey how close he feels science is to an answer.

The first thing Schrödinger does is launch into a discussion on the genome. Based on lessons learned from quantum physics, he arrives at several fascinating conclusions.

For example, he explains why a whole genome might be as small as a few thousand atoms in size. He then goes on to say that if genomes are going to hold hereditary traits over millions of years, then the bonds holding genes together cannot be like molecular bonds that break easily; they must be similar to the bonds in crystals that require a quantum leap in order to change. This means that the genome must take the form of a solidified "aperiodic crystal."

He arrived at this conclusion by looking at what would happen if genes were formed by the traditional weak bonds most often seen in biology: genes would lose their integrity from generation to generation. Crystalline bonds are different. They require a quantum leap to change because the bonds are so strong. This suggests that the genome could contain a digital code that includes enough information to describe how everything in the cell works.

Schrödinger (2001) spent two-thirds of his book on this subject because of the importance he placed on the genome. He had accepted the prevailing theory of biologists in his day that genetic material is the key to what makes cells alive. He concludes this section:

> I tried to explain that the molecular picture of the gene made it at least conceivable that the miniature code should be in one-to-one correspondence with a highly complicated and specified plan of development and should somehow contain the means of putting it into operation. Very well then, but how does it do this? How are we going to turn 'conceivability' into true understanding? (p. 67)

This theory of a one-to-one correspondence between genes and proteins, or between genes and the functions of a cell, was proposed in the 1940's, shortly before Schrödinger wrote his book. However, it was later proved wrong after the human genome was fully mapped (Gould, 2001, p. A15). Nonetheless, Schrödinger is trying to address the hardest part of the problem. He makes this clear when he goes on to say that a model of one-to-one correspondence

> seems to contain no hint as to how the hereditary substance works. Indeed, I do not expect that any detailed information on this question is likely to come from physics in the near future....
>
> No detailed information about the functioning of the genetical mechanism can emerge from a description of its structure so general as has been given above. That is obvious. But, strangely enough, there is just one general conclusion to be obtained from it, and that, I confess, was my only motive for writing this book. (Schrödinger, 2001, pp. 67-68)

In other words, he took his observations about genetic molecules as far as he could, based on the science of his day, but it fell far short of explaining the way organisms actually stay alive. However, he believes that it does point to a significant conclusion about life. This was the reason he felt compelled to write his book. As we will see, Schrödinger now does everything he can to address the real problem head-on. He writes:

> What is the characteristic feature of life? When is a piece of matter said to be alive? When it goes on 'doing something', moving, exchanging material with its environment, and so forth, and that for a much longer period than we would expect an inanimate piece of matter to 'keep going' under similar circumstances. When a system that is not alive is isolated or placed in a uniform environment, all motion usually comes to a standstill very soon as a result of various kinds of friction; differences of electric or chemical potential are equalized, substances which tend to form a chemical compound do so, temperature becomes uniform by heat conduction. After that the whole system fades away into a dead, inert lump of matter. A permanent state is reached, in which no observable events occur. The physicist calls this the state of thermodynamical equilibrium, or of 'maximum entropy.' (p. 69)

Living organisms do something that inert matter cannot: They find ways to avoid the natural process of decay into a state of equilibrium with their environment. This describes the enigma of life.

Schrödinger positions this as a question: How do organisms avoid the natural course of "entropy," which is the change over time that tends to move non-living things to a state of dissipation and disorder? This is what happens when machines wear out and break down, when abandoned buildings erode and collapse, and when pools of energy dissipate. Life, on the other hand, finds a way to retain its order and sustain itself over long periods of time.

Creatures seem to solve the problem of entropy, according to Schrödinger, by eating, drinking, and breathing in material that has a high degree of order. In other words, they gather and extract order from the environment. (p. 73)

Schrödinger admits that this is not easy to picture since "order" does not sound like something we digest or extract from food. He says that other physicists didn't like the idea either and goes on to say he would describe the problem a different way if he were trying to explain this to physicists. Instead, he would ask physicists how living things gather and consume "free energy." (p. 74) However, he does not like this question because, first of all, many people would ignore the word "free" and think that this is just about gathering energy, which misses the real issue, as I will explain later. Plus, as Schrödinger said, a lump of coal contains energy, but this does not mean we can eat coal for food. (p. 74)

Consuming meat and plant material makes more sense, he believes, because it is easier to picture how, after digesting our food, we return it to the earth in a degraded form. This suggests that we may get more than just energy from digestion. There may be something in the complexity of the food we eat that plays an essential role and should not be overlooked. However, there is another reason that Schrödinger prefers to focus on the need for order, rather than energy, in the food we eat:

> What I wish to make clear in this last chapter is, in short, that from all we have learnt about the structure of living matter, we must be prepared to find it working in a manner that cannot be reduced to the ordinary laws of physics. And that not on the ground that there is any 'new force' or what not, directing the behaviour of the single atoms within a living organism, but because the construction is different from anything we have yet tested in the physical laboratory....
>
> These facts are easily the most interesting that science has revealed in our day. We may be inclined to find them, after all, not wholly unacceptable. An organism's astonishing gift of concentrating a 'stream of order' on itself and thus escaping the decay into atomic chaos – of 'drinking orderliness' from a suitable environment – seems to be connected with the presence of the 'aperiodic solids' [DNA], the chromosome molecules, which doubtless represent the highest degree of well-ordered atomic association we know of – much higher than the ordinary periodic crystal – in virtue of the individual role every atom and every radical is playing here. (pp. 76-77)

In other words, the whole reason he is portraying the mystery of life as a matter of order and retaining order is because he sees the genome as the key to how organisms work. Genes represent the highest degree of order known. This is why he believes that life is a process that produces "order from order." (pp. 80-82)

Unfortunately, DNA and genes are not the key to life, as Schrödinger and countless biologists had hoped. And this is easy to prove through a simple experiment. Microbiologists have shown what happens when DNA is removed from a living cell: Surprisingly, it continues to live.

A single-celled organism without DNA cannot live long because it cannot repair damages, and it cannot reproduce, so DNA is clearly necessary for long-term survival. But the cell can and does continue to search for food and avoid threats. It is clearly alive. This is conclusive proof that DNA is not the key to life.

To make this point clearer, I turn to a fascinating lecture given by Craig Venter (2012), a DNA research scientist, in honor of the 70th anniversary of Schrödinger's book, *What is Life?* Venter explains how much biologists have learned over the last 70 years, culminating in some of the remarkable experiments that he and his team have run recently and what they learned.

Venter and his team began by synthesizing virus DNA – creating the artificial DNA molecule-by-molecule in their labs. They then inserted this DNA into an *E. coli* bacteria cell. The *E. coli* cell received the synthetic DNA in the same way as it would accept the DNA of a virus. The cell started interacting with the DNA the way a virus normally would, which was to reproduce more viruses. This proves that DNA itself is just a chemical compound, says Venter, nothing more.

Next, they created an entire chromosome for a living cell (far more complex than a simple virus.) The differences between the new chromosome that they created and the chromosome of the living cell were small – about 90% of the two genomes were the same. But they were still different enough to be recognized as two different species.

Then they disabled the original DNA in the cell, making it non-functional. Note that the cell survives, but it will not be able to live for long without functional DNA. This is why they quickly inserted the artificial DNA after disabling the original DNA. Within a short time, the cell began operating like the new species defined by the new DNA. In fact, it did not take long for the new cell to identify the original, now non-functioning, DNA and treat it as if it were foreign material by "chewing it up" and eliminating it.

> When we interrogated the cells, they had only the transplanted genome, but more importantly, when we sequenced the proteins in these cells, there wasn't a single protein or other molecule from the original species. Every protein in the cell came from the new DNA that we inserted into the cell. Life is based on DNA software. We're a DNA software system, you change the DNA software, and you change the species. It's a remarkably simple concept, remarkably complex in its execution. (Venter, 2012)

This experiment is truly amazing, but Venter's conclusion is not quite right. If "life is based on DNA software," as Venter said, then you should be able to place DNA in a dead cell and see it spring to life. That does not happen. Venter admits that living cells only come from other living cells. This is close to Schrödinger's point about the order of life coming from order. But Venter believes this is about to change:

> Currently all life is derived from other cellular life including our synthetic cell. This will change in the near future with the discovery of the right cocktail of enzymes, ribosomes, and chemicals including lipids together with the synthetic genome to create new cells and life forms without a prior cellular history. (Venter, 2012)

If Venter is right, then every time he takes good DNA and mixes it with the right combination of chemicals in a cellular wall, it will become alive. It should happen every time or almost every time, the same way machines spring into action when we turn them on. Unfortunately, Venter is ignoring the hard problem of life. He offers no explanation for what life is or *how* the right cocktail of chemicals and artificial DNA could suddenly spring to life.

Why would it? All cells die eventually. In most cases, the DNA in dead cells is fine. This means that DNA is not the cause of death in those cases. Then what is? Does the right cocktail of chemicals falter in some way? Is this the cause of death? If Venter is right, then we only need to readjust the mix of chemicals in a dead cell, and it will return to life.

Really? This cartoon picture avoids the question he is supposed to be addressing: *What is Life?* A cell hunts for food and avoids danger for long periods of time. How does a bag of chemistry do that? What keeps the cocktail fueled with the right mix, to keep it alive? How does life create order and sustain that order. No concoction of inert chemistry has ever displayed these traits.

DNA is not the source of life. It is a molecule. Yes, it is a highly complex and highly ordered set of molecular strands that encodes an amazing amount of information. But that information is meaningless without something alive to read it. It does not matter what words are printed in a book if you bury the book deep in the ground; the spots of ink mean nothing by themselves. The paper eventually degrades. Bacteria will digest the paper and will probably enjoy it, but the information encoded on its pages is only meaningful to someone who knows how to read it.

DNA does not tell other molecules what to do; it is simply a molecule itself. Enzymes, proteins, and even ribosomes are all chemicals. If you throw them together, they will react with each other until their chemical pathways take them to the bottom of the energy hill, where the reactions will cease. They will reach equilibrium with the environment. Something more is needed for life. Why do DNA, enzymes, and proteins act differently when they are all together in a living cell?

Every cell that is alive displays a continuing flow of life. The moment the cell dies, that flow starts winding down until it reaches equilibrium with its environment. What changed? Was it the cocktail? Or is there something important in the receptive-responsive relationships between the molecules that changes? There is no evidence that just tossing parts together makes life. The only reason this is so hard for us to recognize is because we are so good at understanding chemical and mechanical reactions that it blinds us to the irreducible relationships of life.

Schrödinger was right that new science is needed to solve this problem. He faced the hard problem head-on. And the reason that a process of order arising from order seems so promising is because we see this same behavior in quantum mechanics. A sense of order and flow becomes clearly visible when temperatures are reduced to near absolute zero. Quantum behaviors then step forward and display themselves, revealing an order between atoms that cannot be explained through cause-and-effect principles.

Machines are made from components that operate consistently based on causal laws. The combination and arrangement of parts in a machine is critical. On the other hand, individual atoms and subatomic particles are moved by dynamic quantum relationships where each individual response is uncertain and unpredictable.

This spontaneous dynamism is always present in the quantum realm. It seems to have a life of its own because we cannot predict its behavior or the relationships that form at the level of quanta. Schrödinger saw a similarity between the way quanta behave and the way organisms relate to each other. This, I agree, is a valuable clue. However, the hard questions still remain: Why do these relationships between quanta arise in the first place? Why do they appear to have a will of their own? Why do we see a similar display in highly complex organisms? And how does the process of life sustain itself in a state of order that is far from equilibrium?

1.3. Werner Heisenberg

Werner Heisenberg offers a different perspective on biological life. In a book that was originally published in 1958, he explains how he interprets a quantum state. He says that a quantum state, sometimes called a "wave function," is mid-way between possibility and reality.

> This concept of the probability wave was something entirely new in theoretical physics.... It meant a **tendency** for something [emphasis added]. It was a quantitative version of the old concept of "potentia" in Aristotelian philosophy. It introduced something standing in the middle between the idea of an event and the actual event, a strange kind of physical reality just in the middle between possibility and reality. (Heisenberg, 1958, pp. 40-41)

> In the experiments about atomic events we have to do with things and facts, with phenomena that are just as real as any phenomena in daily life. But the atoms or the elementary particles themselves are not as real; they form a world of potentialities or possibilities rather than one of things or facts. (p. 186)

Later, in 1971, he uses this perspective to raise an interesting observation about the apparently intentional actions inside living cells and how they compare to the intentional acts of animals:

> Can one really speak of intentions apart from man? At most, we may be prepared to grant that a dog jumping onto the kitchen table "intends" to eat up the sausage. But has a bacteriophage [virus] approaching a bacterium the intention of entering it and of multiplying inside? And even if we are still prepared to say yes, can we also say that genes change their structure with the intention of adapting to their environment? If we did, we would obviously be misusing the word "intention." But perhaps we could choose a more careful formulation. We could ask whether the aim to be reached, the possibility to be realized, may not influence the course of events. If we do that, we are almost back with quantum theory. For the wave function represents a possibility and not an actual event. In other words, the kind of accident which plays so important a role in Darwinian theory may be something very much subtler than we think, and this precisely because it agrees with the laws of quantum mechanics. (Heisenberg, 1971, pp. 242-243)

Heisenberg is saying here that, when actions take place at the quantum level, events do not follow principles of cause and effect. External forces do not define how individual electrons and protons move and interact. What we see instead are quantum possibilities. However, these are nothing like ordinary possibilities. They are potential outcomes that influence what happens next.

We never see this happening when we roll a pair of dice. The outcome is completely random because each possibility is equally likely. But when a photon is emitted by an atom, its actual landing spot is influenced by every possible place it can land. It is as if all these possibilities exist at the same time, and they are all *inviting* the photon to land there. And each of the invitations has an influence on the final outcome. More importantly, these influences interfere with each other. Quantum theory can only give us a statistical picture of what will happen if we run the same experiment over and over because there is no way to determine where a single photon will land.

In other words, Heisenberg is saying that quantum theory shows us that there is another way to look at actions that appear to be intentional or the result of intelligent design. They might not be *planned* choices. They might be *possibilities that influence* what happens.

Can the process of life be the result of possibilities that influence molecules to act in ways that enable life? Did the possibility of flight influence genes in a way that allowed small dinosaurs to evolve from graceful leaping, to gliding, to flying, until they became birds? Heisenberg is saying that this *subtle influence* might be consistent with quantum mechanics.

This is truly an original insight: The mere presence of potential might act as a form of positive feedback that encourages those possibilities to occur. This opens up a new way of looking at what might be happening with the flow of life at the molecular level.

But there is a major problem with this idea: Why would possibilities in the lives of organisms, which exist at much larger scales than genes, influence what happens at the genetic level? Is this even possible? Why would this happen?

Quantum mechanics says that the principle of "superposition," where many possibilities exist at the same time and influence the outcome, does not apply to the macroscopic world. We never see large objects, such as animals, act as if they are in multiple places at the same time. On the other hand, quantum theory has no good explanation for why superpositions exist in the first place. And this means that there is no good reason for suggesting that genes will be affected by future possibilities at the level of organisms. This is why Heisenberg's comment about evolution has generally been ignored.

But here is what makes his comment so enticing: He is saying that "the aim to be reached, the possibility," does in fact influence the course of events in quantum mechanics. This does not mean that these are intentional acts, as he says, but it does resemble the ability to *anticipate*. Anticipation means that future possibilities have a real influence on the choices we make in the present. He is saying that, in a sense, quantum states appear to anticipate what might happen and this may play a subtle role in the evolution of life. Could this quantum ability to anticipate evolve into an ability to act with intention? This is a question worth asking.

Unfortunately, after pointing out this enticing similarity between quantum possibilities and the ability to anticipate, he offers no further suggestions on how this applies to the mystery of life.

However, Heisenberg (1958) does open another useful door. He gives us an historical overview about the best way to resolve this puzzle of biology's hard problem:

> The nearest neighbor to physics is chemistry. Actually through quantum theory these two sciences have come to a complete union. But a hundred years ago they were widely separated, their methods of research were quite different, and the concepts of chemistry had at that time no counterpart in physics. Concepts like valency, activity, solubility and volatility had a more qualitative character, and chemistry scarcely belonged to the exact sciences. (p. 101)

He then points out how similar this is to the situation that biology is in:

> The present relation between biology, on the one side, and physics and chemistry, on the other, may be very similar to that between chemistry and physics a hundred years ago. The methods of biology are different from those of physics and chemistry, and the typical biological concepts are of a more qualitative character than those of the exact sciences. Concepts like life, organ, cell, function of an organ, perception have no counterpart in physics or chemistry. On the other hand, most of the progress made in biology during the past hundred years has been achieved through the application of chemistry and physics to the living organism, and the whole tendency of biology in our time is to explain biological phenomena on the basis of the known physical and chemical laws.... The question arises, whether this hope is justified or not. (p. 102)

Making his point clearer, Heisenberg goes on to say:

> The laws of chemistry could not be reduced to Newtonian mechanics of atomic particles, since the chemical elements displayed in their behavior a degree of stability completely lacking in mechanical systems. But it was not until Bohr's theory of the atom in 1913 that this point had been clearly understood....
>
> Just as in the case of chemistry, one learns from simple biological experience that the living organisms display a degree of stability which…complicated structures consisting of many different types of molecules could certainly not have on the basis of the physical and chemical laws alone. Therefore, something has to be added to the laws of physics and chemistry before the biological phenomena can be completely understood. (pp. 102-103)

In other words, organisms originate actions from within themselves in ways that retain this ability for long periods of time, until they die. Something more than the known laws of physics is needed to explain this trait of biological life. And this situation is similar to how limited our understanding of atoms was before quantum mechanics came along.

Later, in the same book, Heisenberg points out more about this unique quality of organisms:

> The development of biology has supplied us with a great number of examples where one can see that specific biological functions are carried by special large molecules or groups or chains of such molecules, and there has been an increasing tendency in modern biology to explain biological processes as consequences of the laws of physics and chemistry. But the kind of stability that is displayed by the living organism is of a nature somewhat different from the stability of atoms or crystals. It is a stability of process or function rather than a stability of form. (p. 154)

I believe that what Heisenberg is describing is the complex, complementary relationships involved in the continuous process of life. That is how life persists. The proteins, enzymes, and cells change fluidly as organisms grow. The flow of energy, the flow of nutrients and wastes, and the exchanges between organisms and their habitats continue for longer than any known principles of physics or chemistry can explain.

"Stability" sounds a lot like the term "order" that Schrödinger used. However, Heisenberg makes it clear that this is nothing like the static sense of order we find in crystals. This distinguishes what he is saying from Schrödinger's suggestion that genes are aperiodic crystals and that the order of those genetic molecules contains the digital code of life. Heisenberg sees something else. Complex molecules somehow work together in a fluid way to enable the continuity of life. This is what physics and chemistry cannot explain. The process of life keeps going until the creature dies. This is the irreducible nature of life. And there is no way to analyze life by taking it apart. That is why he emphasizes that this is a stability of process or function and *not* a stability of form.

Heisenberg goes on to argue that new science is needed to explain this stable process of life. Until we find that new science, he says, we should continue using concepts like perception, the intended functions of organs, and personal relationships, because they describe functions of living organisms that are real. This is similar to the way chemistry needed to keep using the concepts of solubility, volatility, and valence until the discovery of quantum principles. (p. 104)

> Therefore, it will probably be necessary for an understanding of life to go beyond quantum theory and to construct a new coherent set of concepts, to which physics and chemistry may belong as 'limiting cases'.... If this view is correct, the combination of Darwin's theory with physics and chemistry would not be sufficient to explain organic life.... (p. 104)
>
> If we go beyond biology and include psychology in the discussion, then there can scarcely be any doubt but that the concepts of physics, chemistry, and evolution together will not be sufficient to describe the facts. (p. 106)

Heisenberg goes on to say that most biologists study organisms as if quantum theory did not exist. This is still true today. Biologists hold onto principles of classical chemistry, mechanics, and electromagnetism, leaving them with the unsolved problems of life. Heisenberg says that, if they truly understood the lessons learned from quantum behavior, biologists would realize that their objectified stance is not justified.

As Bohr showed, the stability of atoms cannot be explained by deterministic cause and effect. This is why Heisenberg said above that "atoms…themselves are not as real; they form a world of potentialities or possibilities rather than one of things or facts." He adds this: "Quantum theory does not allow a completely objective description of nature." (pp. 106-107) In other words, the lessons learned from quantum physics should teach us that the deepest descriptions of nature are not completely objective.

It is surprising to see how willing Heisenberg, Bohr, and Schrödinger were to confront the hard problem of biology head-on. Even though they didn't find the breakthrough they were looking for, this could not stop them from exploring every possibility. Their curiosity comes through, and their desire to explore nature's depths for hidden secrets. They were not afraid to ask crazy questions or pursue incomplete ideas just to see where they might lead. They were approaching the mystery of life with fresh eyes, and they knew it. This is what is needed to explore the unknown.

As Heisenberg says, many biologists, even today, assume that we need classical physics and chemistry to unravel the complexities of organisms because quantum effects are limited to the atomic level. But that is not at all how these three founding fathers of quantum mechanics felt. They had faced the most bewildering and confusing challenges of quantum mechanics. Yet, they found their way to establish a new science. They saw similarities with the challenges of biological life that seemed like possible clues. If nothing else is learned from their analysis, we should at least recognize that they all saw that new science is required. They each wrote because they wanted to help start the search anew, to find the pieces needed for what might end up being a shift as big as the one that quantum mechanics brought to chemistry.

However, if this means going beyond physics, chemistry, and evolution to understand life, as Heisenberg suggests, where do we start? Perhaps it is time to turn the tables and approach this from the opposite direction: If Heisenberg is right that biology goes beyond quantum mechanics, and that physics and chemistry are limited cases, can biological life offer a perspective that helps solve the puzzles of quantum mechanics? Can biology give us a new view on why quanta act the way they do? Can this lead to a new theory of life?

2. What Are Quantum States?

Finding quantum effects in organisms is not new to biology; a number of possibilities are now being studied. For example, the sense of smell may be influenced by quantum effects at the molecular level (Marias et al., 2018). The way pigeons find their way home may use quantum effects to enable internal sensing of the Earth's magnetic field (McRae, 2021). And the surprisingly efficient way that energy from photons is gathered during photosynthesis may also be a sign of quantum effects (University of Groningen, 2018). However, all of these cases only take place at or near the atomic realm.

The theory proposed in this series of papers expands the scope of quantum biology beyond the atomic level because it takes us into the realm of relationships between life forms. (For more about the field of quantum biology, see Marias et al., 2018, sections 1 and 2). If this is right, then *quantum* theory is needed to help us solve the mystery of how life works.

However, before we can expand the newly emerging field of quantum biology in such a way that it offers a scientific explanation for how life works, we need a new and deeper understanding of what quantum states actually are.

Heisenberg proposed his interpretation of a quantum state. He calls it a *tendency* for something to happen, similar to Aristotle's idea of "*potentia*." This means that a quantum state is nothing like physical states in classical physics, where objects exist in certain places and move at certain velocities in specific directions.

In classical physics, states of objects can be determined by measuring them. We can know their position. We can detect their momentum. We can measure their mass and energy. We can see the result of a force acting on an object by the way the object accelerates and changes direction because objects have clearly defined properties of their own. None of this is true with quantum states.

We cannot determine quantum states by measuring them because they "collapse" and lose their "quantumness" when they are measured. Quantum states seem elusive, as if they only exist when they are not being observed. Does this sound strange and confusing? You are not alone. Most physicists try not to ask what quantum states are. The first goal of this paper is to find an intuitive way of seeing what they are. With the right lens quantum states can make sense.

Physicists say that something strange happens between measurements. For example, an electron can exist in a state of many simultaneous possibilities of where it is going. But the strangest aspect of quantum states is that all of these possibilities influence the outcome in ways that cannot be reduced to cause-and-effect reactions. Does this sound bizarre? Hang on to that feeling because we are just getting started.

2.1. The Perplexing Problem of Quantum Mechanics

The double-slit experiment is a good way to witness what is most baffling about quantum behavior. If we shoot photons through only one slit, it is easy to describe where photons will hit the screen: We will see a normal bell curve distribution pattern. But, if we open a second slit close to the first slit, white bands will, over time, emerge on the screen where the photons land. We will also see dark bands where fewer photons hit the screen. These dark and light bands are called "interference patterns." And, looking closely, you will see a wave-like pattern, where the white bands are the crests of waves, and the dark bands are valleys between the waves. (See Fig. 1 on right.)

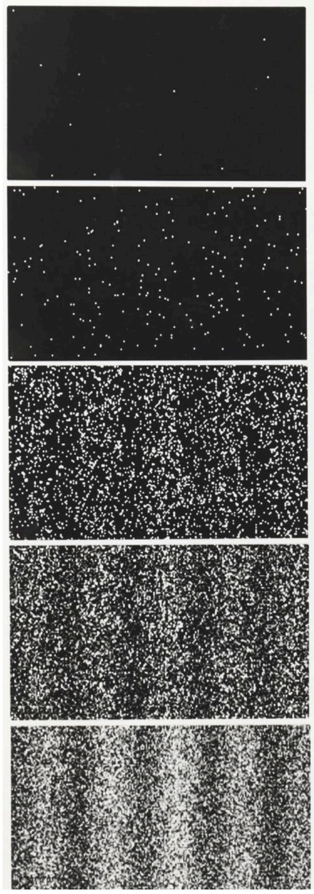

Figure 1: Firing photons one at a time through two slits creates, over time, an interference pattern. (Tonomura, 2006)

If each photon is sent through the slits one at a time, why does opening a second slit stop photons from landing in the dark bands? The problem gets even stranger. If you set up detectors near the slits to see which slit each photon goes through, then the interference pattern disappears. Instead, we see two bell curve patterns (one bell curve centered behind each of the two slits) as if each photon is acting like an individual object with no quantum effects.

Physicists have two ways of picturing *what* is happening in two-slit experiments. Both models are mathematically equivalent, so you can use either one. First, you can imagine the photon as a wave that travels through both slits at the same time, as long as no detectors are measuring the slits. Two wave fronts emerge from the slits and interfere with each other like two waves of water, creating the interference pattern. The problem with this picture is that there is only one *tangible* wave because the photon only hits one spot on the screen. Quantum theory has no explanation for *why* wave functions act this way.

The second way to picture the two-slit experiment is that each photon takes all possible paths to all possible landing spots at the same time. These parallel paths interfere with each other, creating the interference pattern. The problem is that only one photon goes through the slits at a time, so *why* would it take all possible paths? Once again, quantum theory has no answer. These pictures are simply the results of the mathematical models that accurately describe what happens.

This illustrates the quantum puzzle that has troubled physicists for a century. However, if we look closer at these two pictures, something curious jumps out: **Each of the *possibilities*, whether we see them as wave fronts or possible paths, influence each other.** Interference patterns show us that these influences are real.

What makes this interesting is that *the distinction between a cause and an effect falls apart when influences affect each other.* In other words, if two or more influences respond to each other, then we are no longer talking about cause-and-effect reactions because a cause needs to always precede the effect, or it makes no sense to call it a cause. But, when influences have an effect on each other, there is no way to determine which of the influences starts the process. The idea of forceful causation falls apart. Instead, we end up with a complex relationship that is irreducible.

For example, imagine what would happen if the gravitational force of the sun did more than move a planet? What if it also weakened the gravitational force of that planet? If gravity worked this way, the planet would have a similar effect on the gravitational force of the sun. Then, we would no longer be able to study the sun's influence on Earth independently because other planets would weaken the sun's gravitational force, and the sun would weaken the gravitational influence of those planets, which would further affect the sun's force of gravity. In other words, the result would be irreducible.

Something similar appears to be happening in our bodies when organs respond to each other. If we go for a run, our heart beats quicker, our skin sweats, and our lungs breathe deeper. Our brain senses the movements of our legs and arms and keeps them moving smoothly. Our organs are not driven solely by a central processor, they are also responsive to each other.

When influences affect each other, we cannot pull them apart to see their effects separately. They act as one irreducible state. The cause/effect model falls apart. This is the same property that Bohr pointed out when he said that it is impossible to take apart the processes of life to see how life works without killing it. Does this mean that processes of life act as influences affecting each other?

2.2. Problems with Time and Space

The problem gets worse. Quantum theory says that, when they become entangled, two particles share the same quantum state, and there is no way to reduce this entangled state down to anything simpler (Schlosshauer, 2008, p. 4). Hundreds of experiments have proven that entangled states are "non-local," meaning that they reach across space. If one particle is measured, its entangled partner instantaneously alters its state to match its partner, even if they are miles apart, because they share the same state.

From a biological perspective, this is interesting because the cells and organs in our bodies also appear to share states that cannot be reduced, as if they, too, are entangled. And, as Bohr said, the relationships and exchanges that organisms have with their habitat makes it impossible to determine which atoms belong to the creature and which belong to the environment.

If we add this to the fact that quantum possibilities act as influences that affect each other, we now see two of the key behaviors that distinguish organisms from machines: irreducible states and influences affecting each other in ways that cannot be explained by cause and effect.

2.3. The Impossibility of Fully Controlling Organisms

In the introduction, I pointed out a third trait that I said distinguishes creatures from machines: Organisms cannot be fully controlled by outsiders. Does this also hold true for quantum states? **Yes, it does.** In fact, this is one of the most puzzling traits of quanta: We cannot know what a quantum particle will do next. Quantum mechanics accurately predicts the outcome of what will happen if an experiment is repeated over and over, but it never knows how one particle will behave.

The reason for this is that it is not easy to know fully the exact state a particle is in before we measure it. And after we measure a particle, there is always an element of uncertainty of what will happen next. By measuring a quantum particle, we can easily determine the property of one of its states, such as its position. However, the moment we nail down its position, the particle's speed and direction become unknown. Or, if we measure a particle's exact momentum, then its position becomes unknowable. In this case, the particle could be anywhere or everywhere at the same time.

The "Heisenberg uncertainty principle" (Heisenberg, 1983) says that the more accurately you determine a particle's position, the less accurately you know its momentum – its speed and direction. And the more accurately you determine a particle's momentum, the less accurately you know its position. This makes it impossible to control a quantum particle fully.

This means that quantum states display *three key properties* of living organisms.

Biologists studying *the uncertainty principle* have recognized this strange similarity between quantum particles and organisms. In fact, Werner Heisenberg's son, Martin Heisenberg, is a biologist, and he wrote a paper on this subject. He pointed out the remarkable similarity between the uncertainty principle and the free will behavior of living creatures (Heisenberg, M., 2009, pp. 164-165).

Physicists have also written about the similarity between free will and the uncertainty principle. Some have proposed that, in some way, the free will of human beings might be the result of this foundational principle of quantum theory.

> The uncertainty principle is one of the striking revelations of quantum mechanics, and it pervades the theory as a fundamental tenet that cannot be violated.... More interestingly, it is a revelation that seems to address questions of deep philosophical import. With the advent of the uncertainty principle, determinism, the notion that the laws of nature set forth an inextricable course of events from which no deviation is possible, becomes indefensible. According to the uncertainty principle, the exact course of events is fundamentally unknowable. There is always some uncertainty in the physical properties of any given object; not even nature herself knows how this uncertainty will resolve itself.... It's not just a matter of building a better instrument for determining these properties. The exact value is simply unknowable, even in principle. Many have gone on to conjecture that Heisenberg's uncertainty principle is the very source of human free will, but this remains to be demonstrated. (Schumm, 2004, p. 42)

In other words, both physicists and biologists have noticed this resemblance between quanta and living organisms, but no one has been able to explain why such a similarity exists.

2.4. How Quantum States Act Like Biological States

Let's review the ground we just covered.

First, entangled quantum states are irreducible. This means you cannot take them apart to study *why* they are entangled. They simply act as if they share the same state. This shows a remarkable resemblance to what we see in living cells and organisms, where the flow of life also appears to be based on irreducible relationships. We cannot see life after we take cells or organs apart. Does this mean the cells and organs in an animal are entangled?

Second, physicists know that quantum possibilities influence each other in ways that cannot be modeled by cause-and-effect. This is another key property that biologists should recognize in organisms because cells in plants and animals work closely together in ways that cannot be reduced to mere chemical or electrical reactions. Biologists see clearly how DNA and RNA, work together to create new proteins. But, as soon as you add epigenetics into the story, we find proteins acting as regulators of the genes, turning the whole process into a circular loop. This makes it impossible to separate cause from effect clearly. These circular processes run throughout living organisms, creating self-regulating loops everywhere. This is a key trait of life.

Third, both physicists and biologists have noticed that the uncertainty principle resembles the behavior of free will displayed in organisms.

There is another key distinguishing aspect of biological life that I identified in the Introduction: the ability to anticipate. And, in the last section, Werner Heisenberg told us that quantum states demonstrate this same behavior. He says that it is easy to accept the idea of intention when talking about human beings. We might also agree that a dog jumping on a table to eat a sausage acts intentionally. And, if pushed, we might even imagine that a virus is acting intentionally when it invades living cells in order to survive and reproduce. But what if we say that genes act with intent when they adapt to the environment? This is when Heisenberg (1971) says,

> If we did, we would obviously be misusing the word "intention." But perhaps we could choose a more careful formulation. We could ask whether the aim to be reached, the possibility to be realized, may not influence the course of events. If we do that, we are almost back with quantum theory. For the wave function represents a possibility and not an actual event. (pp. 242-243)

The term "wave function" is another name for a quantum state. What Heisenberg is saying, as strange as it sounds, is that quantum states act as possible outcomes that influence what happens. In other words, what *might* happen influences what *does* happen. To put this another way, future possibilities act as real influences on quantum states.

This ability to anticipate does not mean that there is forethought or mental analysis involved, as in the way human beings make a decision. In fact, this was Heisenberg's point: we cannot call this intent. Quantum states do not think. It is more accurate to say that quantum states are affected by the possibilities of what might happen. "Anticipation" is a valid description for this.

Intention is more than anticipation because it includes conscious choice and action. However, our ability to act intentionally is only possible if we also have the ability to anticipate. We would never reach for a goal if we could not sense the potential of that goal. Imagine how powerful the idea of flying was to the Wright Brothers, moving them to dedicate themselves and risk their lives. Intention is only possible if we first feel the motivation that comes from anticipation.

Quantum states seem to possess the same puzzling traits that are unique to life. These are the exact same traits that distinguish living organisms from machines. No wonder many of the founders of quantum theory felt they were on the verge of solving the hard problem of biology.

However, nothing in quantum theory tells us why quantum states should possess the same traits as organisms. Physicists cannot even explain why quantum states act so strangely in the first place. This is why quantum theory has not been able to answer the riddle of life.

Thus, physicists have run into a wall in trying to understand quantum states: What are they, and why do they behave so oddly? Biologists ran into this same wall when trying to explain why creatures are different from machines. Is there a solution to this stalemate? I believe there is.

Physicists have asked if quantum mechanics can explain the origin of consciousness and free will in organisms. However, after seeing all the remarkable similarities between the behavior of quanta and the behavior of organisms, I believe it is time to turn the tables and ask if biology can offer insights that help us solve the mystery of quantum states. This also ends up helping us find a new approach to understanding life.

2.5. A Biological Perspective on Quantum States

After five years of studying the similarities between quanta and organisms, I found myself facing a question that is begging to be asked: Do quantum states possess some of the same properties as life? A biologist might ask the question this way: **Do quanta possess sentience, and is this sentience the source of what makes quantum behavior so strange?**

This sounds like an outrageous suggestion, of course, but it also happens to lead to an equally outrageous prediction that should be easy to prove wrong: If sentience *is* the cause of the irrational behavior of quanta, then we should see living organisms displaying all of these quantum traits. Not just one or two quantum behaviors but *all of them*.

This is exactly the premise I explore in "The Lenses-of-Perception Interpretation of Quantum Mechanics" (Marman, 2018). Let's quickly review quantum behaviors, this time from a biological perspective. But remember, the comparisons that follow are not meant to be convincing. The value in this review is to find a new lens, a new way of looking at what quantum states are and why they behave as they do. Or, to put this another way, what we are looking for are new underlying principles to explain how life works. In the next section, I will summarize the principles. After that, I will test our new lens and new principles. In Part 2 of this ODQTL series of papers (Marman, 2023b), I show how these principles lead to valuable new ways of explaining how life works.

2.5.1. The Quantized Nature of Energy and Matter

A central principle in quantum theory is that energy and matter are always quantized. Individual particles (or "wavefronts," if you prefer that model) are needed to carry energy and mass. These packets cannot be reduced to fractions of a packet. There is no such thing as half a photon.

Quantum theory does not explain why this fundamental law of the universe exists. It is simply accepted as a postulate, an assumption, of quantum mechanics. However, it is a well-known fact in biology that cells and organisms also act as individuals. In fact, their individual nature becomes clear by the way they carry energy and mass, such as the way a bird flies through the air or a sunflower turns its face toward the sun. In other words, it comes down to their intrinsic agency.

You can, of course, cut creatures in half. But an amazing thing happens if you do: They might regenerate from one or both segments into *individual* functioning bodies once again. Or, if you kill them, they no longer act as individuals. Their bodies settle into equilibrium with the environment. **Therefore, all of biological life is quantized as well.**

What is different about this biological perspective is that it offers an explanation for where this individuality comes from: the internal agency of organisms. Not from their energy or mass, but from what they *do* with energy and mass. Can we use this to explain why energy and matter are also quantized?

2.5.2. Indeterminacy

As I said earlier, quantum mechanics can predict accurately the statistical probabilities of where photons will hit a screen, but there is no way of knowing where any single photon will land. This indeterminacy of quantum states is an inherent property, but quantum theory cannot explain *why*.

This also happens to be a natural property of living things. When studying the behavior of single-celled bacteria, biologists can predict how the bacteria will act *on average*, but they have no way of knowing what one bacterium will do in any single case. This is the nature of life.

Biology gives us an intuitive explanation for why this happens: organisms can initiate behavior from within. In fact, they need to continue initiating actions, or they will die. It takes work to stay alive. Once again, this behavior comes down to their agency.

Clearly, creatures are influenced by external forces and constraints, but organisms also possess a form of internal agency. Because they are not machines, they do not follow trajectories blindly, as if they are determined solely by outside forces.

Animals behave as if they possess free will. This is widely accepted by biologists. Treating quanta as if they are alive offers a different way of interpreting what is happening at the quantum level. It adds a strange sense to the indeterminate behavior of quantum mechanics.

This does not solve the problem of where this autonomous ability comes from. And the term “free will” is problematic for two reasons. First, because it suggests causative action that is impossible for outsiders to observe. And second, because it implies independence from external circumstances. But it does help frame the mystery in a new way. It suggests that some form of internal agency is evident in all living creatures, and this may be equally true for quanta as well.

2.5.3. Individuality and Internal Agency Does Not Mean Independence

Here is another surprising quantum trait: Fundamental particles cannot exist independently of their environment any more than living creatures can.

Biologists know that all organisms need air, food, or water to live. If you remove them from that food, they die, as Niels Bohr pointed out. This dependence on the environment is well accepted by biologists. But it is startling to find similar behavior in quanta.

The Standard Model theory of particle physics says that every matter-type particle belongs to a particle field. For example, electrons are members of a universal collective called the "electron particle field." Particle fields give particles their properties of mass, charge, and spin – their company uniform, if you will. This is why every electron has a single negative charge, along with the exact same spin and mass. This is similar to the way properties of organisms are defined by the species to which they belong.

If this represents more than just a similarity between quanta and living organisms – if this is another indication that electrons are alive – then this suggests that, if you remove an electron from its particle field, it will "die" and no longer exist as an electron. This sounds outrageous until we look at how the "weak nuclear force" affects electrons: It causes them to decay – which means they cease being electrons. They stop carrying energy and mass the way electrons do.

And after an electron decays due to the weak force, a new particle is born that suddenly starts wearing the uniform of neutrinos instead. However, this neutrino is not an unrelated new particle because there appears to be a continuation of agency from the electron to the neutrino. In other words, it appears as if the electron dies and is reborn as a neutrino.

The point of this is that every particle belongs to a particle field. In fact, physicists say that it is impossible to separate particles from fields. Physicist, Carlo Rovelli explains it this way: "Fields and particles are the same thing" (Rovelli, 2017, p. 126). **Thus, particles cannot live without fields, and fields cannot exist without particles.**

It is well-known that organisms go far beyond just living and reproducing with others of the same species, they also form societies through personal relationships. In fact, a major part of the time they spend interacting with other organisms is spent with their societies. However, we know that people are the ones who form societies, not the other way around. And relationships with societies largely determine what it means to act as a human being. Therefore, it is clear to us *why* human societies cannot exist without people, and why they shape our behavior. Can looking at the relationship between particles and fields in the *same* way offer physicists a new way of understanding the causal relationship between particles and fields? Like all of the other ideas raised in this section, they are consistent with quantum formalism, making this a valid interpretation. (See Addendum: Deriving Quantum Formalism from LoP Principles)

2.5.4. Entanglement

One of the clearest resemblances between quanta and organisms comes from the baffling nature of quantum entanglement. When particles become entangled, they share a quantum state that keeps them aligned. Experiments have proven that they can stay aligned and share the same quantum state even after flying miles away from each other.

For example, consider two entangled electrons that share a spin state and have opposite spins. Their spins stay opposite for as long as they are entangled. Even when the spin of one is altered by an outside influence, such as by measuring their spin, the other will reciprocate. It does not matter how far apart the two electrons are located.

How do they know how to stay aligned when they are miles apart? More importantly, *why* do particles become entangled in the first place? Quantum theory cannot explain *why*.

However, biologists and psychologists have long noted a resemblance with human relationships and entanglement. Gerardo Adesso (2007) and other physicists have written about this. A great example comes from Jeremy Bernstein (2009) about the physicist John Bell who liked to explain entanglement by referring to

> identical twins who had been separated at birth. Bell discovered that there were a number of pairs that had been reunited later in life to find that they had a remarkable number of things in common, including smoking the same brand of cigarette. (p. 172)

These physicists were not trying to suggest that quantum entanglement is actually happening in human relationships. Not at all. They were simply using human relationships as examples because it offers a helpful way of picturing how quantum entanglement works.

Think about what this means to human beings. We often feel an affinity and sense of rapport that aligns us with our friends. We complete each other's sentences. We laugh at the same jokes. We feel pain when they suffer and thrills when they have success, as if we share those feelings.

We share a sense of alignment with our loved ones. No matter how far away they might be, we still feel "close to them." They are in our thoughts during the day because they seem to tug at us inwardly. In our closest relationships, we share a kind of private emotional space with others, even when we are not able to talk to them or send them messages. It is well-known that this often happens in a much stronger way between identical twins.

If we use third-person lenses, where we position ourselves as outside observers, the suggestion that electrons could be emotionally involved seems preposterous. They are just electrons, tiny bits of matter. How could they feel emotions?

That is a perfectly valid question. But, if we treat third-person lenses as the only way of finding truth, then why do our own subjective feelings and experiences have such a real influence on us? Emotions move us. They alter our behavior in countless ways, but not as outside forces. They emerge from our relationships with others. Feelings of attraction also exist between us and our pets. These feelings are, indeed, mutually shared experiences.

This shows how using only one lens of perception can blind us: It can prevent us from learning and seeing new possibilities simply because we have not yet seen how they make sense through another lens. As a result, it is easy for us to reject, unconsciously, perspectives that seem alien to our way of seeing. And what I am suggesting here will, unfortunately, seem alien to many physicists.

However, the unexpected nature of reality keeps forcing scientists to look at the world in new ways. This is why we need to keep trying on new lenses, to see where they take us, no matter how uncomfortable they make us feel at first. This means crossing through a zone of confusion that can be unsettling before it starts to make sense. We should never let this hold us back if we really want to understand. This describes the present challenge we face with both quantum mechanics and the hard problem of biology.

Psychologists see human entanglement emerging naturally between human beings. When we are born into a family, we take on many of the same traits as our brothers and sisters. When lovers begin living together, they align themselves without even thinking about it, and they continue to feel aligned even when they leave each morning to work at different companies. If we align closely with others on a team, we attune with them subconsciously to make our work flow more smoothly.

What if entanglement *is* the result of relationships? What if entanglement includes some kind of inner dynamic similar to emotions? Can this help explain the mysteries of quantum mechanics? Honestly, the only reason to ask these questions is because there is such an incredibly long list of resemblances and similarities, all pointing to the same possibility.

2.5.5. Attraction and Repulsion

This leads to another fascinating resemblance: At the quantum level, electrons are not repelled by all other electrons, and they are not always attracted to every proton (Kastner, 2015, pp. 84-87). It is a well-known fact that like charges repel and opposite charges attract, but at the quantum level between individual particles, actual attraction and repulsion are rare events.

If you have two foam balls charged with billions of added electrons, they will *always* repel each other. But on the quantum level it is hit or miss. This sounds a lot like the emotional nature of relationships; they are unpredictable. We never know for sure who is going to hit it off.

We all know at least two friends who are not attracted to each other, even though we like them both. Yes, we see a general sense of attraction between men and women, but this certainly is *not* true in most cases. The experience of emotional attraction between human beings is actually rare, which is what makes it special.

Physicists have determined that attraction and repulsion between electrically charged particles are also rare. For example, the odds of two electrons actually repelling each other is about 1 out of 137. This is known as the "fine structure constant." (Kastner, 2015, chapter 5)

Physicists also say that attraction and repulsion are triggered by invisible quantum exchanges between them (Kastner, 2015, chapter 5). This is described mathematically as virtual particles passing back and forth between charged particles. Virtual particles are intangible – there is no way to measure them directly. This process of attraction and repulsion can also be described as invisible wave functions (or quantum states) that carry no energy and either add together or cancel each other out.

But why does one pair of particles hit it off when another pair does not? Quantum theory offers no explanation. Third-person lenses offer us no way to explain this mystery. But we know how it feels to be attracted to another person. It is often unexpected. If the other person confirms that they feel the same way about us, then the experience of "chemistry" between us is reinforced and grows stronger. When we act mutually on shared feelings towards each other, a relationship grows to become substantial and real, creating new emotions that have a powerful effect on our behavior.

Our personal experiences give us an intuitive way of relating to the unpredictable nature of relationships. It feels as if something invisible to outsiders does pass between us and others. As a result, we feel drawn to some and want to run far away from others. Can this explain why charged particles have hit and miss relationships as well?

2.5.6. Wave-Particle Duality

Particles are notorious for displaying two different types of behavior: They show both particle-like and wave-like properties (Penrose, 2016, pp. 133-138). For example, photons act like particles when they light up one spot on a screen. They look more like waves when they create interference patterns.

We see a similar dual behavior with organisms. The particle-like nature of organisms stands out when they act as individuals. On the other hand, their wave-like nature shows up when they are involved in the back-and-forth exchanges in relationships. This is especially noticeable when they are involved in social relationships, similar to the way particles belong to fields.

Look at the shape of a rose: Its beauty arises from the delicate folds and ripples of its petals formed by countless living cells working in concert. All life forms are involved in continual exchanges with the world – the rhythmic breathing in and out, beating of hearts, and the inflow and outflow of material exchanges with their habitat. Wave-like behavior is easy to see.

All creatures are affected by the groups they are involved with. This raises the question: Does the wave-like nature of quantum states come from the inner dynamics of personal relationships?

2.5.7. The Uncertainty Principle

Dead bodies don't push back. They settle into equilibrium with the environment. They do not oppose external forces. On the other hand, it is a fundamental trait of sentient agents to resist attempts that try to limit and control them. If this is right, then perhaps Heisenberg's uncertainty principle is *not* the source of free will. Perhaps the opposite is true: The need of quanta to act as sentient agents *is* the cause behind the uncertainty principle.

2.5.8. Exchanging Energy

Here is another similarity: Ruth Kastner shows that real particles continually circulate and exchange energy. If they ever stopped circulating and exchanging energy, there would be no way of knowing if they exist in our universe because there would be no way to detect them. In other words, particles become tangible only through transactions of energy. (Kastner, 2013, p. 16)

According to Kastner, this circulating and exchanging of energy comes down to the emission and absorption of energy.

We see a similar trait with organisms: They can only survive if they continue gathering and expending energy. This means consuming (absorbing) food and eliminating (emitting) waste. In other words, life forms must engage in continuous work with the world in order to live in it.

Instead of asking "*What is life*?" Nick Lane (2015) says that we should ask *What is living?* Living, he says, is about the gathering and use of energy (pp. 50-52). Now we see why: All living things must work to live in this world. Quantum particles must *also* work to exist in the world. If they are not absorbing and emitting energy, they are not *real* particles, they are only *virtual* particles.

2.5.9. The Impossibility of Studying Quanta in Their Pure State

There is no way to see how quanta behave in their natural state. We can only observe how they act when they are being observed. Trying to study living creatures runs into the same difficulty. Observing them alters their behavior because, as anthropologists know, animals also observe and respond to us. Thus, living with gorillas to study them alters their natural state.

Taking creatures apart to study their organs gives us a better idea of their anatomy, but it also brings an end to their life. It is as if a wall exists that obscures our ability to see what makes organisms alive. The same is true when we measure a quantum state – it loses its quantumness. The result of this is that quantum states cannot be seen directly by outside observers. This is why a third-person lens is not enough to show us what quantum states are. We need a new lens.

2.6. Quantum Behavior between Living Organisms

The Lenses-of-Perception Interpretation of Quantum Mechanics (Marman, 2018) differentiates itself from every other interpretation of quantum mechanics by its prediction that we should see quantum behavior *wherever living organisms form relationships*. This is necessary if this interpretation is right. It cannot be avoided.

If quantumness is caused by sentience and the forming of relationships, then we must see these seemingly irrational behaviors at the macroscopic level as well. We should find the same exact patterns of entanglement, superpositions, uncertainty, the quantization of energy and matter, and wave function collapses at every level where life forms, acting as individuals, relate to each other.

Quantum theory states that quantum effects disappear as you move from the microscopic level to the world of big things. If this is true, then the quantum theory of life that we are exploring here can be proven wrong by showing one principle of quantum behavior that is not working at the level of organisms and human beings. Even one example of a true quantum effect is enough to prove that the LoP Interpretation is wrong.

That should be easy, but it isn't. I have not been able to find a single case that proves this wrong. All of the behaviors that we observe with fundamental particles that give us the "sense of unease that quantum mechanics communicates," as Carlo Rovelli puts it (2008, p. 1), can be seen in our lives as human beings and in the behavior of all organisms, even single-celled amoebas.

We have reviewed the similarity between entanglement and human relationships. We know that both particles and organisms are carriers of energy and matter. Therefore, they both act as if they are individuals, and the energy and mass of both life forms and quanta is always quantized. This is why we never see a living creature that is half alive. Biologist Alan Rayner and I wrote a paper on this exact subject (Marman and Rayner, 2016).

We also saw above how the indeterminate and unpredictable behavior of quanta is similar to the willful behavior of living creatures, and how particles and organisms display both a particle-like and a wave-like nature.

This leaves two essential quantum principles that I have not yet addressed: superpositions and wave-function collapse. Both of these functions are considered unique to quantum theory.

Niels Bohr says that quantum behavior seems so strange to us because there is nothing in quantum theory to suggest that we will ever see these properties operating at the human level or in the lives of organisms. This is especially true for superpositions since they disappear so quickly as we move from the subatomic realm to the macroscopic world.[2]

I have been saving the functions of "superpositions" and "wave-function collapse" to explore them in detail. I want to analyze them much more rigorously because they play such important roles in solving the puzzle of life.

However, what makes all of these resemblances between quanta and organisms so interesting is that, when we examine these traits from a biological perspective, we find a deeper understanding of why these behaviors might exist at the quantum level. In other words, comparing the behavior of quanta with organisms leads to an intuitive way of interpreting entanglement, uncertainty, wave-particle duality, and all the other bizarre traits of quantum mechanics. More importantly, the insights we gain from quantum physics offer us a potential solution to the hard problem of biology.

We are opening doors to a theory for how life works that derives from quantum principles. As soon as we have this explanation in hand, we can begin testing it to see if it holds up. I define the theory and start testing it in Part 2 of this ODQTL series (Marman, 2023b). That is where things get really interesting.

3. New Principles Needed for a Theory of Life

After centuries of using third-person lenses to study the natural world as scientific observers, it might seem wrong to consider any other approach as valid. It might feel as if any other lens is not scientific because what we see through subjective perceptions cannot be measured or verified, and the emotions we experience in personal relationships are not objective either.

Clearly, outsiders will never be able to confirm the reality of subjective experiences or the emotional dynamics in relationships, but the reason for this is not hard to understand: third-person lenses, by definition, include only outsider perspectives. This does not mean, however, that we must abandon the scientific process of careful analysis and reasoning followed by experiments designed to test our theories. There are ways to make sure that what we are doing is "science."

For example, as outsiders using a third-person lens, we can frame a clear hypothesis that is testable. We can look for challenges to the hypothesis and make sure it withstands these challenges. We can search for facts that contradict or disprove the theory. We can expose the theory to general criticism and critical review by others. And, most important of all, the real

[2] Some interpretations of quantum mechanics, such as *The Many Worlds Interpretation*, claim that the wave function does not collapse, it splits up, taking multiple parallel paths, with only one path existing in our world. The other paths are said to exist in other worlds. The LoP Interpretation disagrees with this claim because it implies that we, as human beings, must also have parallel lives in parallel universes. If we exist in parallel physical universes, why don't we have awareness of our other lives? More importantly, if we are not aware of them, how can they be our lives? The main reason this theory of multiple parallel universes was proposed is because quantum theory cannot explain why wave functions should ever collapse. I will explain how and why wave functions collapse later in this paper, eliminating the need for the Many Worlds Interpretation.

test of a theory is its ability to offer new insights that lead to new discoveries. Can it make unexpected predictions that can be tested? Can it solve problems? Does it open new doors for research?

Nobel prize-winning physicist Giorgio Parisi (2023) says, “Scientific discovery isn't always initially about data and deduction. Intuition also plays a powerful role.” He then lays out the typical phases that go into developing a new theory:

- There is a first, preparatory stage in which the problem is studied, the existing literature is read, and the first unsuccessful attempts at a solution are made. It is a period that…ends because no progress occurs.

- Then there is a period of incubation in which the problem is abandoned, at least consciously.

- This incubation ends suddenly with a moment of illumination, which often occurs in a situation unrelated to the problem you’re trying to solve. It might happen, for instance, when conversing with a friend about topics with no apparent connection to the problem.

- In the end, after the illumination provides the general way to tackle the problem, the solution must actually be formulated. This can be a very protracted period. First, you must verify that your idea is correct and whether or not the road you have set out on can work. Following this, come all the mathematical steps required to demonstrate the solution.

When it comes to understanding life, biologists hit a wall and have largely abandoned trying to solve the problem deductively. They are waiting for a moment of illumination, an aha! moment, when a new lens clicks into place. It now looks as if the wall biologists hit might be directly related to the wall that physicists hit with quantum mechanics. And, if the theory proposed in this series of papers is right, these two walls might be directly related to what philosophers and scientists call “the hard problem of consciousness.” These three problems appear to be entangled.

I believe that both Lee Smolin and Carlo Rovelli are right: What is needed is a set of principles from which quantum theory can be derived. Rovelli explains this well:

> Special relativity is a well understood physical theory, appropriately credited to Einstein’s 1905 celebrated paper. The formal content of special relativity, however, is coded into the Lorentz transformations, written by Lorentz, not by Einstein, and before 1905. So, what was Einstein’s contribution? It was to understand the physical meaning of the Lorentz transformations… We could say – admittedly in a provocative manner – that Einstein’s contribution to special relativity has been the interpretation of the theory….
>
> Einstein was so persuasive with his interpretation of the Lorentz equations because he did not append an interpretation to them: rather, he re-derived them, starting from two postulates with terse physical content – equivalence of inertial observers and universality of the speed of light – taken as facts of experience. It was this re-derivation that unraveled the physical content of the Lorentz transformations and provided them a convincing interpretation.

> I would like to suggest here that in order to clarify the physical meaning of quantum mechanics, a similar result should be searched: Finding a small number of simple statements about nature – which may perhaps seem contradictory, as the two postulates of special relativity do – with clear physical content, from which the formalism of quantum mechanics could be derived. In other words, …. [finding a] set of physical facts from which the quantum mechanics' formalism can be derived. To my knowledge, such a derivation has not been achieved yet. In this paper, I do not achieve such a result in a satisfactory manner, but I discuss a possible reconstruction scheme.
>
> The program outlined is thus to do for the formalism of quantum mechanics what Einstein did for the Lorentz transformations: 1) Find a set of simple assertions about the world, with clear physical meaning, that we know are experimentally true (postulates); 2) Analyze these postulates, and show that from their conjunction it follows that certain common assumptions about the world are incorrect; 3) Derive the full formalism of quantum mechanics from these postulates. I expect that if this program could be completed, we would at long last begin to agree that we have understood quantum mechanics. (Rovelli, 2008, p. 2)

For this paper, I am adopting Rovelli's strategy, developed to address the challenges of quantum physics. However, my goal here is, first and foremost, to solve the hard problem of biology. It just so happens that this strategy can also open a door to deriving the formalism of quantum mechanics. See the Addendum: Deriving Quantum Formalism from LoP Principles.

As Heisenberg says, if we solve the mystery of life, then we may learn that quantum mechanics and chemistry are only "limiting cases," and the need for something more is even clearer if we include psychology along with biology. Today, there is no scientific theory of life. Solving this mystery first, from fundamental principles, may open the door to also making sense of quantum theory and the hard problem of consciousness.

However, I think describing the problem this way makes it sound simpler than it is. The real challenge before us is that the lenses of perception we have learned from centuries of studying chemistry and physics have been holding us back. Yes, we need do need to retain the use of third-person lenses, as if we are only outside observers, when we formulate our theories and when we test them. Yes, this does assure that we are doing science. But, making sense of these theories requires more.

I propose here that three fundamental lenses of perception are needed to find the underlying principles for which we are looking. The third-person lens used by science is one of these lenses. But this lens that science has been using for hundreds of years clearly ignores two important properties of life: Physics and chemistry both leave out first-person perception and the lens that we use when forming relationships, which I call "second-person perception." I call it second-person perception because we relate to others when we see the "you" in other beings and they see the "you" in us.

The hard problem of consciousness is all about explaining where first-person perception comes from. This is truly the hardest challenge faced by science because first-person perception is purely subjective. The whole point of the third-person lens is objectivity. To practice physics and chemistry, we set aside our subjective experiences. Only then can we see clearly how reactions and mechanisms work. And that *is* enough to make sense of machines and lifeless molecules. But it may not be enough to understand life.

Most biologists agree that organisms show signs of agency. The problem is explaining where this agency comes from. How do creatures originate behavior within themselves? If we view this agency as a sign of first-person perception, then this changes the meaning of agency. It leads to a simple and almost obvious postulate: Agency is only possible if the agent possesses first-person perception. This raises questions: Does this explain why organisms are quantized and act as individuals? Does the same principle also apply to fundamental particles? If quanta are sentient agents that act as individuals, does this mean they also possess first-person perception?

This, of course, is not a new idea. As Dombrowski (2020) says, Plato proposed something similar thousands of years ago. However, this leads to a problem with duality. Objectivity and subjectivity appear to be opposites, and it appears that they represent the whole story. This is where the mind-body puzzle comes from. How does mind, which means our first-person perception, control our body? This duality appears to be the original source of all three walls that physicists, biologists, and the scientific study of consciousness have run into.

This tells us that third-person and first-person lenses are not enough. The issue of duality and the mind-body problem disappear as soon as we include second-person perception. Relationships between sentient agents offer a solution to this age-old puzzle.

Personal relationships are complex and mind-boggling to comprehend, especially when we try to understand them from a third-person perspective. Friendships and love affairs are unpredictable and irrational, but they are also some of our most meaningful experiences. And they have a huge influence on the choices we make. Physicists and chemists have ignored the dynamics involved in personal relationships.

Second-person perception is often overlooked because we are stuck on the idea that objectivity and subjectivity tell the whole story. Many scientists think the solution to duality is to propose that brains somehow create consciousness. But the "chemistry" we experience in personal relationships *is not objective* because it cannot be felt or perceived by outsiders. It is private. And second-person relationships *are not subjective* because they are shared experiences. Second-person relationships create the bridge between the objective "real" world and subjective perceptions that belong only to us.

More importantly, these lenses – first-person, second-person, and third-person – are related to each other. It is time to set down the foundations of the Lenses of Perception Interpretation.

Postulate: Consciousness comes first, before anything else, and consciousness always belongs to someone as first-person perception. This is a postulate, an assumption, a statement made without proof. Yes, the idea that consciousness comes first contradicts common scientific assumptions, just as Rovelli said our founding postulates might. On the other hand, the idea that consciousness only exists in the form of first-person perception is consistent with our experiences.

This postulate explains why organisms and quanta act as individuals. The assumption at the heart of quantum mechanics – that matter and energy are always quantized – now makes sense. Matter and energy are quantized because they are carried by sentient agents that have first-person perception. This applies to all life forms as well. And it tells us that consciousness does not just float out in space on its own; it belongs to someone.

Now let's look at the principles:

Principle One: Perception begins with the sensing of differences. This is a well-known discovery of psychology, from the study of perception. It is listed as the first principle here because it leads to all the other principles. It applies to all conscious beings with first-person perception, whether they are quanta or creatures. In fact, this principle and all of the following principles *must* apply to all sentient agents, or the theory is invalidated.

This principle plays a role in quantum mechanics because entanglement strength is determined by how distinct the shared states are, as we see in Part 2 of this series (Marman, 2023b, pp. 39-40). There are cases of both strong and weak entanglement. Maximal entanglement is only possible when shared states are as distinct as "up and down" or "black and white" (Schlosshauer, 2008, p. 33). Stark differences also make for stronger relationships between organisms, as I show in Part 2.

Principle Two: As soon as we become conscious of others, we see the difference between "self" and others. This distinction leads to the natural desire to know more about others. This is when we see the "you" in others. However, as we know, sentient beings do not form relationships with everyone. They are drawn to some and repelled by others. A relationship can only form when beings have a shared interest in each other. The bond is stronger when it is rare. Here again, stark differences make perceptions stronger, and this directly affects relationships. This is significant because it means that perception is not just a passive act of observing, as we see with third-person perception. *When it comes to personal relationships, perceptions are creative.*

Seeing possibilities in relationships makes the bonds stronger. When we see potential in a child, we actually encourage them, because how others see us changes how we see ourselves. Perception *is* creative. This is why finding a meaningful relationship changes our lives. Physics and chemistry ignore these dynamics of personal relationships, but not biology because relationships play such a major role in the lives of creatures.

Principle Three: Personal relationships are shared states that are private because they only exist between those involved. Two people in a relationship share a private space that exists only between them. Our first-person perceptions *do* belong only to us as individuals, but our relationships *do not*. We cannot own a relationship because our relationships with others are shared second-person states. The feelings that pass back and forth between friends and lovers are invisible to outsiders. As we will see later in this paper, this explains why quantum states cannot be detected directly. This back-and-forth exchange in personal relationships also creates a wave-like property because the way beings perceive each other affects them in creative ways, which further changes their perceptions.

And because these dynamics in personal relationships are hidden to outsiders, they do not exist as part of the outer, objective world. They are real only *between* those that are involved. Not to outsiders. This fits exactly with what Heisenberg said, that wave functions describe a reality halfway between possibility and reality. This is the bridge between subjectivity and objectivity.

Note: The subconscious (also called "unconscious"), is an integral part of our relationship experiences. It comes before conscious thought is possible. Psychologists have proven this through countless experiments (Dehaene et al., 2021, p. 43-56). The difference between subconscious and conscious perceptions can easily be distinguished when sensations are too short in duration to reach conscious awareness. We also see this clearly with first impressions. We will see an example of this in the next section. Research shows that unconscious experiences influence our perceptions in dramatic ways.

What is less known is that the subconscious comes to us through a second-person lens. Carl Jung learned that people in our dreams do not feel as if they belong to us. We see them as "not-I." He also found the subconscious has no center, no first-person viewpoint. (Marman, 2016, pp. 105-110) I show that this is because all subconscious influences spring from relationships (pp. 278-288). This is what makes quantum behavior seem so bizarre, as we will see later in this paper.

Principle Four: The shared, hidden reality of what is experienced in private relationships leads to third-person perceptions because we are outsiders to the relationships of others. We cannot enter the private space of others unless we are invited. And if we are invited and join in, then it is now a personal relationship that we belong to. We are no longer outsiders.

Third-person lenses show us only the public world that we share with other outsiders, in an *impersonal* way. The friendships and affairs of others are invisible to our public view. This is how nature hides its secrets from prying eyes. This leads to the experience of a public reality that we call "the world out there." We share this reality with all sentient beings in the universe, but these third-person perceptions are impersonal. They do not move us the way personal relationships do because they do not involve us. This is the world of facts that science has studied for centuries. But this also explains why third-person lenses have not been able to crack the mystery of life.

These four principles apply to all organisms and quanta. They show how first-person, second-person, and third-person lenses are related, and why these three lenses are directly involved with what is happening at the quantum level. These principles give us important clues in the search to find a quantum theory of life.

Now we must address two crucial issues that need to be resolved using a scientific process:

1. How do organisms anticipate possibilities, especially if they have no brain?
2. And how do they act purposefully?

Both questions go to the heart of the mind-body problem, but asking these questions reformulates the problem. Rather than picturing the mind as if it is some kind of *thing* that is subjective and conscious, we will look, first, at how organisms with *first-person perception* anticipate the future and how this influences their actions. Second, we will ask how they act to achieve a goal?

This is a much better formulation for solving the mind-body problem because it turns out that these key abilities – anticipation and purposeful action, which are possessed by all living creatures – are also mirrored by two well-known quantum behaviors: *superpositions* and *wave-function collapse*. I will take a close look at both, one after the other. I hope to show that these two quantum properties work *exactly the same way* as the biological properties of *anticipation* and *purposeful action*, respectively. And both of these abilities spring out of personal relationships, which is why they will never be understood completely by using only third-person lenses.

In the next two sections, I will analyze this hypothesis objectively to show that it holds up. We will start by looking at anticipation and how this relates to one of the strangest elements of quantum theory: superpositions. Then we will plunge into the mysteries behind the measurement problem of quantum mechanics. This leads to a new quantum theory of life that is introduced in Part 2 of this ODQTL series (Marman, 2023b), where I will begin testing the new theory by challenging it from many perspectives.

The premise of this theory is that *superpositions* and *wave-function collapse* exist in all living organisms for the same reason they exist in quanta: they are the results of sentience. In other words, only sentient entities with first-person perception *anticipate* and *act with a purpose*. Only sentient entities with first-person perception have superposition states and wave-function collapse. And *both of these abilities come into existence only through second-person personal relationships*.

These next two sections will be the first test of the principles that underlie the LoP Interpretation. If this premise is correct, then, the principles underlying what is happening at the quantum level and in the lives of organisms are not just similar, they are the same. And, by comparing these two functions from both the biological level and the quantum level, we find deeper insights into what these behaviors mean to *both* quantum mechanics and biology.

In other words, by integrating the views from two different fields, quantum physics and biology, we gain added insights into both. For years, biologists have been using the lens of quantum physics to learn more about biology. We will use the biological perspective to help us learn about quantum mechanics. This is the best path to take if Heisenberg (1958) was right that "*it will probably be necessary for an understanding of life to go beyond quantum theory and to construct a new coherent set of concepts, to which physics and chemistry may belong as 'limiting cases.'*" (p. 104)

4. Superpositions and Anticipation

The main reason why physicists say quantumness does not extend beyond the subatomic realm is because superpositions disappear as particles interact with their environment. If this is true, then it should be virtually impossible to find superposition states in relationships between organisms. At first blush, this sounds as if it invalidates the theory that sentience is the cause of quantum behavior. If we cannot find superpositions involved in the lives of organisms, then the fundamental foundation of the LoP Interpretation will be proven false.

However, before we can determine if this destroys the LoP Interpretation, we need to clearly understand superpositions. Only then can we know what to look for at the level of organisms. The best way to see what physicists mean by superpositions is to return to the two-slit experiment.

If photons are sent one at a time through the slits, and there are no photon detectors at the slits, then even nearby particles have no way of knowing which slit the photons go through. In this case, if we run the experiment over and over, we will see an interference pattern build up as the photons hit the screen. This tells us that these photons are not just going through one slit or the other. Something else is happening. It appears to outside observers as if the wave function of the photons goes through both slits at the same time and interferes with itself.

This is not just true for photons. Electrons, other fundamental particles, and even small atoms display the same phenomenon. But as objects grow larger, the interference fades. It is nearly impossible to see interference patterns when objects are large enough to be seen with our eyes.

Quantum formalism says that we must treat the two slits as two possible paths to the screen and that both possibilities exist at the same time. In other words, the two possibilities are superimposed on top of each other, which is why they are called "superpositions."

As Roger Penrose (2016) explains, we must not think of this as if there are two particles "and" each goes through a different slit. If that were the case, we could use the ordinary notion of "and" to describe what is happening. We cannot use "and" because there is only one particle going through the slits at a time. We cannot use the notion of "or" either. The particle does not go through one slit "or" the other because, if this were true, no interference pattern would develop. Superposition is a unique state, not just because multiple possibilities exist at the same time, but because those possibilities have an influence upon each other. This is what creates the interference pattern. (p. 24)

If you roll a six-sided die, it will end up on one of its six surfaces. These six possibilities *do* exist at the same time before the die settles onto one surface, but the possibilities *do not* influence each other. The die simply lands on *one* of the six surfaces *or* another.

The idea of superpositions is so baffling that physicists needed a long time before they accepted them as real. The evidence is now indisputable. As I showed before, here is how Heisenberg (1958) describes this weird quantum behavior:

> This concept of the probability wave was something entirely new in theoretical physics.... It meant a *tendency* for something [emphasis added]. It was a quantitative version of the old concept of "potentia" in Aristotelian philosophy. It introduced something standing in the middle between the idea of an event and the actual event, a strange kind of physical reality just in the middle between possibility and reality. (pp. 40-41)

Let's look at two other well-known examples of superpositions.

Quantum theory says an electron can exist in different places at the same time. The probability of where you will find it decreases with distance. Thus, from time to time, there is a possibility that an electron will appear on the other side of an impermeable wall if the wall is thin enough. One moment it can be on one side, the next moment it is on the opposite side without going through the wall. This is exactly what happens, and the property is used in transistors. The process is called "tunneling" because it looks as if the electron tunnels through the silicon wall. However, it doesn't actually tunnel, it just leaps to the other side where it gets involved in something happening there.

Here is a second example: An electron does not orbit the nucleus of an atom like a planet orbits a sun. That outdated idea has been proven wrong. Physicists know that the electron does not travel a distinct path around the nucleus because, if it did, it would lose orbital energy and eventually fall into the nucleus. Instead, electrons act as if they are suspended in a stable energy state in relation to the nucleus. Quantum theory says the electron is in a superposition state of all possible positions inside an electron shell around the nucleus. You can think of this as if the electron is a droplet of water that does not exist in one place because it is spread out as a cloud of vapor that surrounds the nucleus, except this cloud is a cloud of possibilities.

Why do quanta act this way? Why do superpositions exist at the quantum level? It is important to know that traditional quantum theory has no answer except to suggest that it has something to do with quanta being wave-like when they are not observed. This means that an electron can literally be spread out across a region of space. It does not actually move through space to get to another location. It just appears there. This is often called a "quantum leap." The problem we face in this chapter is that we never see organisms or human beings leaping around this way.

However, the story changes as soon as we understand what superpositions *are*. Let's use a biologist's lens, rather than a physicist's lens, to make sense of what this means to organisms. Then we can test this idea to see if it holds up. A biologist's lens might ask: Can superpositions be more than possibilities? Can they be *possibilities that exist in personal relationships between sentient life forms*?

The best way to understand this is with an example: Think about choosing which friend you want to invite to lunch. All your options have an influence on you and weigh on your decision. You could call up one friend or another. Or you might even ask a few of them to come at the same time. But a group lunch creates complications because some of your friends may not like each other. These conflicts are what create interference patterns. Before you make a decision, all of your possible options have an influence on you because you *anticipate* how your relationships will be affected by whom you choose. You *feel* what it means to invite one friend and not another.

This biological view shows us that all of our relationship possibilities influence us at the same time, when they shape our decisions. This is the same effect that superpositions have on quantum states. The question is: Is this just a similarity, or are they the same phenomenon? Let's look closer.

Relationships are complex because they are open-ended, and the choices we make impact them. We feel this impact *emotionally*, whether we think about it consciously or not. Plus, as soon as we act on a possibility – for example, by inviting a friend to lunch – all the possibilities collapse down to one actuality. This is exactly what happens when a wave function collapses. But now we can see why all of the other possible options vanish: because we made a choice. They disappear as soon as we act on one. This makes perfect sense when talking about relationship possibilities.

This gives us an intuitive hypothesis about what superposition states are: **They are personal relationship possibilities between sentient agents. A relationship state is defined by all of the possibilities that exist in all of the relationships related to that state at that time.** This comes directly from Principles Two and Three listed in the last section. More importantly, understanding what superposition states *are* solves one of the biggest challenges to deriving quantum formalism from principles. (See the Addendum: Deriving Quantum Formalism from LoP Principles.)

Relationships thrive on possibilities: Friendships and love affairs flourish and grow as long as there are shared hopes and dreams. On the other hand, as soon as we try to analyze relationships by shifting to an objective lens, we step outside of our emotions. This is like death to relationships because using an outsider's view only shows us what *is*. This is like throwing cold water on the potential dreams that enliven our lives. Relationships are empty without possibilities.

With friendships and love affairs, we feel the incredible power of anticipation. It is clear that what *might happen* in a relationship does, indeed, affect *what does happen*. Looking forward to what is possible influences every relationship decision we make. This suggests that superpositions should only exist *between* sentient beings. And they must disappear when we move to the level of things that are conglomerates because *conglomerates* are not sentient – they are not moved by possibilities. This resolves another major mystery in quantum theory: Why do quantum effects disappear in the macroscopic world, making objects act more like lifeless matter?

All of this makes sense when looking at human affairs, but now we need to find a compelling reason for why this should also apply to the quantum level. Fortunately, there are good reasons.

4.1. Relational Quantum Mechanics

In the 2008 revision of his paper, "Relational Quantum Mechanics," Carlo Rovelli (2008) explains that there is a fundamental trait of quantum systems that makes them so bewildering:

> In this paper, I discuss a novel view of quantum mechanics…. based on a critique of a notion generally assumed uncritically…. The notion rejected here is the notion of [an] absolute, or observer-independent, state of a system…. The thesis of the present work is that by abandoning such a notion (in favor of the weaker notion of [a] state…relative to something), quantum mechanics makes much more sense. (p. 1)

Rovelli is saying here that there are good reasons for saying that quantum states do not exist on their own. This explains why they cannot be studied by outside observers, because they only exist in relation to "observers." He goes on to say that this single change in how we view quantum states overcomes "the sense of unease that quantum mechanics communicates." (p. 1) The point he is making is that quantum states are *only* relational states.

In a recent article, Rovelli takes this even further – saying that "relationships are the key to existence" (Rovelli, 2022).

Independent of Rovelli, another famous physicist, David Mermin, proposed a similar idea. In his 1998 paper entitled, "What Is Quantum Mechanics Trying to Tell Us?" Mermin writes:

> My complete answer to the late 19th century question "what is electrodynamics trying to tell us" would simply be this:
>
> ***Fields in empty space have physical reality; the medium that supports them does not.***
>
> Having thus removed the mystery from electrodynamics, let me immediately do the same for quantum mechanics:
>
> ***Correlations have physical reality; that which they correlate does not.***

> The first proposition probably sounded as bizarre to most late 19th century physicists as the second sounds to us today; I expect that the second will sound as boringly obvious to late 21st century physicists as the first sounds to us today.
>
> And that's all there is to it. (Mermin, 1998, p. 2 on arXiv copy)

Unfortunately, Mermin later abandoned his theory because, as he explained in a letter to me, his idea raises a question he could not answer: "Correlations between what?" Fortunately, LoP Interpretation resolves this problem by saying that these correlations are relationships between sentient agents. And, yes, it is easy to see why sentient agents *do not seem to have physical reality* because they cannot be seen or detected through scientific measurements. As Neils Bohr said earlier, we cannot see the actions of sentient agents, only the actions of their bodies. Thus, the point Mermin makes in his paper holds up if we replace "correlations" with "personal relationships between sentient agents."

Rovelli and Mermin, both highly acclaimed physicists, show us that seeing quantum states as only relational states seems to resolve the most confounding aspects of quantum mechanics. However, this does not validate the theory I am proposing that *superposition states represent relational possibilities* because neither Rovelli nor Mermin use the term "relational" or "correlations" to mean the kind of dynamic, personal relationships that exist between living creatures. In fact, Rovelli goes to great lengths to avoid associating any kind of consciousness with these relations. But this turns out to create contradictions that lead to fatal flaws in his theory. Rovelli (2008) writes:

> By using the word "observer" I do not make any reference to conscious, animate, or computing, or in any other manner special, system. I use the word "observer" in the sense in which it is conventionally used in Galilean relativity when we say that an object has a velocity "with respect to a certain observer." The observer can be any physical object having a definite state of motion. For instance, I say that my hand moves at a velocity *v* with respect to the lamp on my table. Velocity is a relational notion...and thus it is always (explicitly or implicitly) referred to something; it is traditional to denote this something as the observer, but it is important in the following discussion to keep in mind that the observer can be a table lamp. (p. 3)

In other words, Rovelli is using a purely third-person perspective for his description of quantum states, even though he admitted earlier (p. 2) that they possess no such independent third-person reality. This approach *does* work in classical physics when referring to velocity, as he points out. However, it *does not* work with quantum states, as I have explained before (Marman, 2018):

> An experiment by Dumé (2007) shows that if the path an electron takes through two slits becomes "known" by even one other particle, such as a nearby electron, the interference pattern fades by a measurable amount. If two or more particles "learn" the path of the electron, the interference pattern fades even further (pp. 3-9).
>
> If there are enough particles near the slits that it is possible for equipment to learn the path that an electron takes with a high degree of accuracy, then the interference pattern disappears completely.

> In other words, the real reason that the specter of consciousness looms over QM is because the spread of information is crucial to how quanta respond. However, most physicists wave away the role that consciousness plays by taking the same position that Rovelli (2008) took….
>
> Unfortunately, this avoids the real problem… Why do quanta alter their behavior when they gain information? For example, why do photons hit different places on a screen depending on whether the environment "knows" which slit they pass through? [Using a third person lens] does not make this problem at the heart of QM go away.
>
> Further, Fields (2012) shows that to assume a "Galilean" observer (as do Rovelli and most physicists) makes the observer too "informationally impoverished" to work in quantum physics. A quantum observer must, at a minimum, be able to alter its state in response to information that it receives. Acting as a passive reference point is not enough (pp. 92-119).

In other words, when we say that a quantum state is a relational state, this must be more than a passive correlation. A "Galilean" observer is not enough because quantum states have an influence on how quanta behave. We cannot ignore the fact that quanta are influenced. What influences them? Perhaps relationship possibilities, which is why it is valid to call this "anticipation."

I agree with Rovelli's point that the "observer" does not need to be a human being or a cat, but, when talking about quantum states, a table lamp does *not* work. As Mermin says, the dynamic nature of quantum states is so significant that only the correlations seem to matter, not the particles. Certainly not a table lamp.

When a photon is faced with many possibilities of where it might be absorbed, a table lamp is not an option. Physicists know this. It is almost always an electron that absorbs the photon. And that electron is almost always in an atom. Yes, the atom might belong to a lamp, but it is the possibility of an electron absorbing the photon that affects where the photon lands. We know this because all of the possibilities interfere with each other, and this determines the probabilities of where the photon actually lands. Therefore, treating quantum states as relationship possibilities between sentient agents explains superposition states accurately. Plus, it makes a lot more sense.

After all, we know from our human experiences that relationships are bewildering. They often seem irrational. They do not follow rules of logic. Relationships can appear spontaneously and unexpectedly, and they can disappear just as easily. This is exactly what makes superposition states so hard to understand as well.

However, Rovelli and Mermin give us no explanation for *why* quantum states exist only as "observer-dependent states," as Rovelli puts it, or purely as "correlations," as Mermin says. Isn't this just as unsettling and perplexing as the mystery of quantum mechanics they are trying to solve?

The underlying principles of the LoP Interpretation lead us to an answer; and, strangely, this explanation emerges after we see that the same principles apply equally to both superposition states and the personal relationship states of organisms.

There is another difference between the LoP Interpretation and how Rovelli interprets what he means by relational quantum mechanics. As we saw before, Rovelli wants to find new principles:

> "quantum mechanics will cease to look puzzling only when we will be able to derive the formalism of the theory from a set of simple physical assertions ('postulates,' and 'principles') about the world." (Rovelli, 2008, p. 2)

Rovelli thinks this principle – that quantum states are only relational states – is a good starting place to derive quantum formalism from simple principles (p. 2). However, this one principle has not been enough to complete his goal. Why? Because *all* of the steps in quantum formalism must be explained, and this one principle from Rovelli does not explain the wave function collapse step. As a result, Relational Quantum Mechanics (RQM) is not a complete interpretation.

A recent paper by Kastner (2023) shows that Rovelli and Mermin's theories face fatal flaws because they assume that quantum states only evolve in a linear, unitary manner, which means that quantum states cannot make sudden breaks. However, sudden breaks are exactly what must happen during a measurement to arrive at one result. The many possibilities always reduce to one choice. Kastner also shows that newly discovered inconsistencies falsify the basic postulate of RQM. The reason that RQM is proven false is because quantum states stop being purely relational when they are measured. Quantum states actually become objective when measured. (pp. 1-10)

In section 5, I show how the wave function collapse process emerges naturally from the principle of relational states *if* quantum states are relationship possibilities between sentient agents. This leads to a complete interpretation, achieving Rovelli's hope. This suggests that both Rovelli and Mermin were right about the importance of quantum states being relational when it comes to describing the property of superposition states, but this is not enough because a different process is needed to explain how measurements end up with one actuality. When measured, quantum states become visible to third-person observers as objective matters of fact. This is an important step in what makes the outer world look solid, with a reality of its own.

LoP principles show us not only that superposition states are always relational, they also show us what superposition states *are*, why they are responsive, how consciousness is involved, and why they are invisible to outsiders. This new picture tells us that pure coherent quantum states and wave functions do not travel through both slits at the same time as real waves carrying energy that travel through space, because they are nothing more than relationship *possibilities* between a photon and all the potential landing spots on the screen. In section 5, I will show how this leads to a much more accurate description of what happens during measurements.

But now that we understand this, we need to return to our earlier question about superpositions: Why don't we see people making quantum leaps from one place to another?

4.2. Being in Multiple Places at the Same Time

The reason we never see people in different locations at the same time is because we are looking at their bodies. Bodies are made up of billions of particles. That is the wrong thing to look at. If the four founding principles of LoP theory are right, then superpositions are nothing more than *relationship possibilities between sentient agents*. This is why quantumness fades away when we look at large conglomerates, like a mound of dirt, because conglomerates are not sentient.

There are billions of electrons jumping around in the electron shells of the atoms in our body. What effect does this have on the position of our body? Virtually none at all. Billions of electrons would have to leap in exactly the same direction at the same time to make a detectable difference. This never happens because each leap comes from a different personal relationship at the quantum level, making it *impossible* for the electrons to all leap together. This is why *bodies* of organisms never leap from place to place.

It turns out that we never see electrons in multiple places at the same time either. Whenever we measure their location, they are always in one place because measuring collapses the wave function. Electrons only exist in a quantum state of being in multiple places at the same time when they are *not* being measured.

This new interpretation of superpositions and quantum states changes the story about human beings and whether they leap from place to place because it tells us to stop focusing on their bodies. What we need to look at is **the intangible internal agents who inhabit their bodies.** Here is the question we need to ask: Can we, as internal agents, be in different places at the same time?

Yes, we can, because we inhabit our whole body.

When we are upset by bad news, we feel it in the pit of our stomach. We cheer ourselves up by singing a song. Songs and emotions move us. Where do they move us? To a different place than the pit of our stomach. Perhaps our heart center?

We also become aware of our heart center when we are with our lover. But when we think about the world, it seems as if we are watching images on a screen in our head. Sensations, sounds, and feelings create ripples through our body. At any moment, we can be anywhere in our body or be associated with our whole body at the same time. We are not limited to being in one place until we specifically move our focus of attention there. Then we make a quantum leap to that place.

This might sound like nothing more than subjective impressions, but the experiments of Roger Sperry (1968) with people who had the nerves cut between the left and right hemispheres of their brain (to prevent convulsions) prove that each hemisphere of the brain processes sensory data independently from the other. Sperry showed that, even after their operation, these people still used both the right and left hemispheres of their brain, depending on the situation. And when using one half, perceptions from the other side simply faded into the background, the same way we ignore sounds coming from another room when we are engaged in a conversation. (pp. 723-733)

In other words, we leap back and forth between the two hemispheres of our brain whenever we shift our attention (pp. 723-727). Sperry (1964) also showed that these people never felt as if they were split in two, and their families noticed no changes in their behavior (pp. 41-52). They and their families experienced them as the same single individuals that they were before their operations (p. 46. See also Bayne 2008). Sperry won the Nobel prize for his research. (For a longer review of Sperry's discoveries, see Marman, 2016, p. 307-311)

Recent experiments take this much further. Research shows that, when vision is conscious, our attention oscillates back and forth between our left eye and right eye. We cannot look consciously through both eyes at the same time because our attention can only be on one eye at a time. If our brain is just a computer, it should process the data from the left eye and right eye in parallel. In fact, it does exactly that in the early stages of visual processing. But this process changes radically when vision reaches our conscious awareness, as Stanislas Dehaene (2014, pp. 30-31) explains:

> [These experiments prove] that what matters to consciousness is not the initial stage of peripheral visual processing (where both [left and right eye] alternatives are still available) but a later state (at which a single winning image emerges). Because our consciousness cannot simultaneously apprehend two objects at the same location, our brain is the seat of a fierce competition. Unknown to us, not just two but countless potential perceptions ceaselessly compete for our conscious awareness – and yet at any given time, only one of them makes it into our conscious mind. Rivalry is, indeed, an apt metaphor for this constant fight for conscious access.
>
> Is this rivalry a passive process, or can we consciously decide which image will be the winner of the fight? When we perceive two competing images, our subjective impression is that we are passively submitted to these ceaseless alternations. That impression is false, however: attention does play an important role in the cortical competition process....
>
> But most important, the very existence of a single winner depends on our giving it our attention; the fighting arena itself, as it were, is made up of the conscious mind.

In other words, conscious seeing is different from the early stages when we subconsciously relate to visual sensations. Whenever we see consciously, we view images from one eye at a time. At the subconscious level, however, visual sensations are evaluated *in parallel*, like all of the quantum superpositions that influence the outcome at the same time.

Moving our focus of attention is the same thing as making a choice, and, when we do, only one of the possibilities is selected. Why one eye and not the other? It could be something glimpsed through our left eye that catches our attention, or there might be something in the right eye's field of view that intrigues us. Or, we go back and forth to create a 3-D picture. This is the way vision works when visual perception becomes conscious.

Images are not actually "competing" with each other, as if this is a rivalry. Remember, these are relationship possibilities. Images from both eyes are felt subconsciously at the same time, the same way superpositions exist as relationship possibilities, but only one can make it to conscious perception at a time. This describes perfectly the process of how superpositions lead to a wave-function collapse: A possibility becomes real to us the moment we move our attention to it.

This shows the way many superpositions influence us at the same time. As Dehaene says, this may sound like a passive process, but it isn't – because our attention is involved. One of the many possibilities crosses the threshold of consciousness only when we shift our attention to it.

Imagine the relationships we have with all our cells and organs. It is easy to forget about them, as they are subconscious, until we get hungry or need to go to the bathroom. Then they cross the threshold of our perception. Our attention also shifts suddenly when our heart beats erratically or we feel short of breath. In other words, the relationships between us and the cells of our bodies influence us with possibilities all the time. This is what it means to inhabit a living body.

Electrons appear to inhabit an atom in the same way. They can be everywhere in an energy shell around an atom. They also leap from one shell to another. They can spread out like a cloud, or they can be in just one place when they are measured.

We experience this same bizarre quantum behavior. Where do we, as beings, sit in our bodies? As Dahaene (2014) points out, ancient philosophers asked where the seat of soul is, and they offered a wide range of answers: Hippocrates and Hierophilus said the seat of soul is in the brain. Democritus and Aristotle said that soul exists throughout the body. Epicurus put the seat of soul in the stomach; the Stoics, within and around the heart. Strato placed the seat of soul between the eyes. (p. 7)

They all seem to disagree, but, in fact, they do not. They are all correct because, as conscious beings, we can move our focus of attention to any place in our body. Or we can be everywhere in our body if we stop focusing our attention on any one spot and feel all of the relationship possibilities we have with all of our cells and organs at the same time. This is exactly the way superpositions work. Thus, we *can* be in many places within our body at the same time.

4.3. Relationship Possibilities with Others

However, the most noticeable experience of superpositions for human beings comes from the relationships we have with other people. All of those relationships also influence us at the same time. They are always there in the background, shaping our lives, whether we realize it or not.

Should we move to another country to take a promising job if it means leaving our lover? Will we take time from a busy workday to buy a gift for our child's birthday? Which friend should we call when we need to talk with someone? Superpositions represent the possibilities in our personal and private relationships. We experience them through a state of anticipation that wavers between *all* of the possibilities. Where we put our attention – that makes a difference. Only relationships that are watered with our attention will grow.

Therefore, we live with both the possibility of moving to take a job in another country and the possibility of not moving because being near our lover is more important. We anticipate both *states* at the same time. And it is clear that these possibilities *interfere* with each other. Both options weigh on us until our scales tip one way or the other. They do not force us. This is not cause and effect. They only influence us. However, the moment we act on one of the possibilities, it becomes tangible, and the others disappear – those options no longer exist.

This describes exactly what happens when a wave function collapses. It collapses when one of the many intangible possibilities is acted upon. It then creates a tangible change. This shows how conscious choice gives birth to the visible phenomena of our natural world.

According to this theory, we should see superposition effects wherever we form relationships with others. We do, and we experience this in our daily lives. Of course, this is not scientific proof. However, seeing how this works in the lives of organisms and the behavior of quanta leads us to a deeper understanding because it shows us that this ability to originate behavior from within, which distinguishes biological life from machines, takes place in two stages.

First comes the state of superposition. Physicists call this the pure quantum state. It is a state that cannot be seen directly by outside observers because measuring collapses this state. In this first stage, relationship possibilities influence us subconsciously as vague feelings. All the possibilities wash over us, canceling each other and adding to each other, like waves. But our attention has a subtle effect: Without us realizing it, as soon as we give a relationship our attention, that bond grows, even if it is adversarial. And, without our attention, relationships die.

This is perception before it becomes conscious. And this shows how sentience acts as a state of anticipation, where the possibilities of relationships push and pull our attention and affect our choices. Psychologists have a term for these subconscious perceptions: “apprehensions.”

Before sensations and urges to act can emerge into conscious perception, they exist in a form that is too subtle to describe precisely with words because we only see the possibilities of what they might be. For example, the moment we walk into a room filled with people, we sense the mood in the room subconsciously. Before we notice details, we feel a sense of attraction or repulsion. We form impressions of strangers the same way.

Our first impressions are not precise. They are vague and amorphous before becoming clear enough for us to recognize them consciously. Picture these first impressions as being on their way to becoming comprehensible, but they have not yet arrived at a state where they are distinct enough for our conscious mind to perceive. Psychologist William James (1899) offers a glimpse into the strange world of apprehensions:

> The gist of the matter is this: Every impression that comes in from without, be it a sentence which we hear, an object of vision, or an effluvium which assails our nose, no sooner enters our consciousness than it is drafted off in some determinate direction or other, making connection with the other materials already there, and finally producing what we call our reaction. The particular connections it strikes into are determined by our past experiences and the ‘associations’ of the present sort of impression with them. (p. 157)
>
> A child will call snow, when he sees it for the first time, sugar or white butterflies. The sail of a boat he calls a curtain; an egg in its shell, seen for the first time, he calls a pretty potato; an orange, a ball; a folding corkscrew, a pair of bad scissors. Caspar Hauser called the first geese he saw horses, and the Polynesians called Captain Cook's horses pigs. Mr. Rooper has written a little book on apperception, to which he gives the title of “A Pot of Green Feathers,” that being the name applied to a pot of ferns by a child who had never seen ferns before. (pp. 159-160)

When we see something for the first time, our subconscious makes associations with things that it knows. Big flakes of snow look like white butterflies to a child, the first time they see snow. Our subconscious looks for the closest match until it gets to know what it is actually sensing. A sail on a ship looks like a curtain, until we see how it captures the force of the wind.

Our subconscious learns by forming a relationship with the new thing we are seeing, whatever it might be. And it forms relationships by experiencing the impressions and putting attention on them. More experiences make distinctions clearer by reinforcing them. Thus, children learn what an orange is by eating one. They get to know what snow is by seeing, feeling, tasting and playing with it. We get to know strangers by spending time with them and doing things together. This is how we learn from experience at a subconscious level before we can consciously think about it.

This first stage is when relationship potentials affect organisms subconsciously. They *feel moved* by the possibilities. The feelings come as emotions, not thoughts, and they have a clear influence on life forms. Quanta respond to superposition quantum states this same way.

While we have found a way to relate intuitively to what quantum states are and how they exist between living organisms, this still feels squishy because it seems so subjective. Fortunately, this is only half the story. It is time to move to the second half, where we find the process that shapes the objective world.

This second stage is when the wave-function collapses. This is when sentient agents respond and act. A choice is made when we act on one of our relationship possibilities, such as when we turn down a job offer in another country to stay with our lover. This action collapses all the other options and makes that one possibility real. It is no longer a possibility; it is now objectively real and measurable.

This collapse that causes the shift appears random to outsiders. There is no way to know which possibility will be selected because the choice always emerges from relationships between sentient beings. Remember, this is one of the principles that tell us that both quantum states and wave collapse must emerge from relationships between sentient beings. This proved true for quantum superposition states. Now let's look at exactly how the wave-function collapse process works.

5. Wave Function Collapse and Purposeful Action

To say that superpositions can be seen at the level of animals and human beings goes against the accepted wisdom of physicists today. This should not be possible, making it truly surprising to find validation for this radical prediction of our emerging quantum theory of life.

However, when it comes to suggesting that the wave function also collapses at the level of human beings, this is not new. Physicists began proposing this idea in the early days of quantum mechanics. In fact, human observation was seen as a possible *cause* for the wave-function collapse after physicists discovered that superpositions only evolve in a linear, predictable manner. This means that wave functions can only change gradually. However, when a measurement is made, a quantum state seems to make a sudden, instantaneous, non-linear collapse to a single actual result.

5.1. Wave Function Collapse and the Act of Observation

In 1932, physicist John Von Neumann (1955) published the first, fully rigorous, formal analysis of quantum mechanics. He showed that a wave-function collapse acts like a completely different process from the gradual evolution of pure quantum states. (pp. 352-353)

Up until then, the most popular explanation for what happens when a wave function collapses was that it occurs when a purely quantum state "mixes" with measurement equipment that is in a classical state. However, Von Neumann realized that equipment needs to be treated as a quantum system as well.

In other words, we cannot treat the equipment as merely a "lamp," as I said in the last section, because we need to look at the interactions of the fundamental particles. He then showed that any equipment involved in a measurement becomes entangled with the quantum state under test. As a result, the equipment is no longer independent of the object being measured. If this is true, then this state should continue to evolve gradually and linearly. It should not change suddenly.

Then how does a wave-function collapse occur? After looking at the overall process, Von Neumann (1955) could see only one place when something sudden and discontinuous seems to happen: when the observer of the experiment observes the results. This act of conscious recognition creates an instantaneous shift in information. That is the moment when the results suddenly become the knowledge of the observer (pp. 418-421, see also Von Neumann-Wigner Interpretation, 2023). In other words, Von Neumann was suggesting that the "quantum leap" that happens with a wave-function collapse does not represent an actual physical process but is triggered by a sudden change in the scientist's knowledge (Penrose, 2016, p. 144).

This is not that different from the sudden change that happens when something emerges from our subconscious and suddenly enters our awareness, as we discussed in the last section, or when we shift our attention from our left eye to our right eye, when vision becomes conscious.

However, even though many physicists were strongly committed to this idea in the early days of quantum mechanics, the consensus has changed. Today, almost all physicists agree that the observer's consciousness is *not* the key determiner of the outcome of measurements. This does not mean that scientists agree on how to explain what happens when a wave function collapses to one result. Not at all. But it does show that physicists have learned a lot over the last ninety years.

Experiments in the early twentieth century were not nearly as advanced as today. When they first ran the famous experiment where photons are fired one at a time through two slits, they were surprised to see an interference pattern build up over time from where the photons hit the screen. How do single photons going through these slits create this wave-like pattern? Does each photon go through both slits at the same time? Is each photon interfering with itself?

To answer this question, physicists set up detectors next to the slits to see if the photons were going through both slits or just one. When they ran the test this way, every photon was detected passing through only one slit. But the interference pattern suddenly disappeared at the same time. Somehow, detecting the photons instantaneously stopped their wave-like behavior.

They ran the experiment again, leaving the detectors in place next to the slits, except they turned the detectors off. The interference pattern returned. Photons regained their wave-like properties. This is why physicists began asking if the act of observation could be causing the photons to lose their wave-like "coherent" quantum state. But in the last 30 years, experiments have become far more sophisticated. There is now strong evidence that this process of losing coherence, which is called "decoherence," causes the interference pattern to fade gradually, not suddenly.

Decoherence theory says that, when a particle interacts with other particles in the environment, the particles become entangled, and when this happens information about the particle spreads throughout the environment. Isabelle Dumé (2007) describes an experiment that I referred to in the last section. It shows that, if the path that an electron takes through two slits becomes "known" by even one other particle, such as a nearby electron, the interference pattern fades by a measurable amount. If two or more particles "learn" the path of the electron, the interference pattern fades further. (pp. 3-9)

Decoherence theory says that the information spread by nearby particles causes the loss of the interference pattern. Therefore, a particle retains its full wave-like state only when it is not being "observed" or "measured" by other particles.

Note the shift in who the observer is: Human observers of the experiment are no longer seen as causing electrons to lose their wave-like nature. It is nearby particle "observers" that produce this effect because they spread information about which slit an electron is going through. Physicists now know that electrons can lose their wave-like properties gradually, not suddenly.

Does this mean that physicists now treat particles as sentient observers? No. When you use only third-person lenses and look at everything as an outsider, that idea does not even seem possible. They simply see the spreading of information as the result of particles becoming entangled.

After the science of decoherence was introduced, most physicists abandoned Von Neumann's way of thinking because entanglement with particles in the environment, not human observers, appears to cause the interference pattern to disappear. A number of experiments have validated this theory. But this is not the end of the story because the loss of coherence still does not explain how a wave function collapses all possibilities down to a single result.

A great deal of confusion was created by Von Neumann's theory. But, remember, the reason he introduced consciousness in the first place was because he was searching for any process that could create a sudden, non-linear, shift. Coherent quantum states only evolve gradually, but the end result of any measurement is always one actuality. Why does a photon hit one particular point on a screen and not others? Why does a photon choose one slit when it is measured and not the other? Even founders of decoherence theory admit that decoherence does not solve this problem and quantum theory cannot explain it. (Joos, 2003, pp. 4-5 and p. 357)

It is not easy to find the kind of non-linear process Von Neumann was looking for because, as Newton's laws of motion show, forces work by accelerating objects. This means that they only create gradual changes. You would need an infinite force to create a discontinuous shift. Thus, we come face-to-face with "the measurement problem," the biggest hole in quantum theory.

5.2. Finding a New Lens for the Measurement Problem

John Von Neumann made a mistake. He confused quantum effects happening at the human level (when humans observe an experiment) with quantum effects between particles.

According to the LoP Interpretation, quantum behavior *does* happen at both levels, but the levels should not be mixed because **quantum effects only occur when sentient agents form relationships with each other.**

Photons do not form personal friendships with humans any more than physicists get emotionally involved with the particles in their test equipment. However, particles do display repulsion and attraction to other particles, and humans feel forces of repulsion and attraction to other human beings and sometimes to animals, especially their pets, or sometimes to the plants in their garden.

Most scientists do not realize that a solution to the measurement problem now exists. It is still treated as an unsolved mystery by many physicists. This is important because, if I am going to show that a wave-function collapse is the same thing as *purposeful action*, which is the goal of this paper, then I need to explain exactly what happens when the wave function collapses.

Let's put this problem in perspective: Niels Bohr, Erwin Schrödinger, and Werner Heisenberg all felt that they were close to unraveling the mystery of life, but they ended up hitting a wall. Well, the measurement problem is that wall. And as I said in the Introduction, this is the same wall that biologists ran into. They all ran into this blockade because they have not been able to explain the non-linear change that happens during a measurement. And they cannot see what happens when measurement occurs because any attempt to observe coherent states destroys their coherence, the same way that attempting to take living organisms apart to study them kills the flow of life. This is the mystery we are trying to explain.

There are two parts to the measurement problem. First, and most important, we need to know what counts as a measurement. What exactly happens when all the possibilities collapse down to one result? Second, what is it that determines the final outcome? We need to find a new lens that shows us the answer to these two questions.

Let's start with a subject we know well: human relationships. Are there good examples of when relationships between human beings change suddenly? Yes, there are: when people get married.

One of the issues that makes a wave-function collapse look mysterious to physicists is that the outcome is not determined by outside forces alone. Quantum theory says that, before a measurement, we can only know probabilities about the results, never which actual outcome will turn up. We find this same unpredictability in relationships between people. No one, not even the people involved, know which relationships will develop into lasting friendships or marriages.

Outside influences, such as friends, family, and society in general, can have significant effects on the outcome, but the fate of a relationship is ultimately determined by what develops between those involved. When it comes to a couple that decides to move in together or get married, a shared decision is made. In that instant, the gradual evolution of their friendship suddenly shifts.

Getting married is a *purposeful act*. It is also irreversible because all of the possibilities of whom to marry collapse down to one: marriage to one person. Even if the couple later splits up, each person going their separate ways, there is no going back to the same friendship they had before because being married changes their relationship in a way that is irreversible. This is why, immediately after an intentional act, it is true that all other possibilities (for marriage) disappear.

These are the same traits we see when a wave-function collapses: It is a sudden, discontinuous event that is irreversible. As a result, when it collapses, time flows in only one direction because once we make a choice and act on it, the other options disappear. After that, new possibilities emerge. This is why, every time we act *for a purpose,* we experience time flowing forward, toward the future, where new possibilities draw us on to see what might happen next.

A photon landing on a screen can be compared to a swimmer in a turbulent sea, where the hands of friends are reaching out from the rocky shore. Which hand (which atom on the screen) will the swimmer (the photon) grasp? It all comes down to choosing one relationship over another, while the sea is rising, falling, and churning all around with relationship possibilities.

In other words, wave functions only collapse when a single possibility emerges out of all the possibilities as the one worth acting on. One relationship stands out. We saw this in the last chapter when one eye sees something that captures our attention and causes us to look. Because first-person perception is singular, we can only see consciously through one eye at a time. The same thing happens when meeting someone for the first time. The possibilities of friendship evolve through time until it becomes clear that we both see each other as friends. That is when it becomes real. Then we start acting as friends. Before we can act on a goal, a clear choice must emerge.

This gives us a new lens – a new way of looking at the wave-function-collapse process. And it shows us how this same process can lead to purposeful action at the level of organisms. But we still have a long way to go if we want to explain the measurement problem at the quantum level. We now have to test our new lens: Our new way of interpreting a wave collapse needs to match *exactly* what quantum particles go through when they are measured.

5.3. The Where and When of Measurement

The new theory of life proposed in this series of papers says that life is a quantum process. Unfortunately, until recently, no theory has been able to explain why quantum behavior should exist in relationships between life forms. We now have a reason: Quantum behavior is the result of relationships between sentient agents. The next big roadblock has been the measurement problem. This is just as important for completing quantum theory as it is for explaining life. Robert Griffiths (2017) explains:

> ...the failure of quantum physicists to solve the measurement problem(s) is not only an intellectual embarrassment – surely it is that, as pointed out by some leading physicists...but also a serious impediment to ongoing research in areas such as quantum information, where understanding microscopic quantum properties and how they depend on time is central to the enterprise. (p. 2)

Swiss physicist Nicolas Gisin (2018) gets to the heart of the problem: A physics theory, like quantum physics, should, fundamentally, tell us how to perform a measurement:

> Here quantum theory is surprisingly silent. Often it is said that one should couple the system under investigation to a measurement apparatus, frequently called a pointer, and

> then measure the latter.... Hence, to measure a physical quantity…of your quantum system, you should measure another system. This is the infamous shifty split, as the pointer itself should be measured by coupling it to yet another measurement system, and so on. (p. 1)

The problem Gisin is getting at here is that quantum formalism does not really explain how, based on quantum principles, a measurement takes place. Physicists use equipment – which means a classical device – to somehow measure the quantum system under test. Physicists realize that quantum processes must be involved, but all they can see is that the measuring equipment ends up *pointing* to one specific result. Just one actuality. What happened to all of the other possibilities? If you want to look closer, to see the quantum processes taking place, then you need a second set of equipment to measure what is happening between the quantum system and the first equipment.

Then you will need to run a third test, and a fourth, on and on forever, because measurement equipment is made up of too many atoms to see what makes the many superposition possibilities collapse down to one actual result. In fact, if the LoP Interpretation is right, measuring equipment will never show us what makes a wave function collapse because the cause always emerges from the relationship dynamics between sentient agents that are invisible to outside observers.

As soon as we use equipment and make a measurement, the original quantum states disappear because they were relationship possibilities and one was selected. Thus, measurement produces a collapsed state, making it impossible to see what happened to all the other possibilities.

Gisin goes on to say that this wall we run into seems to suggest

> that the world is made out of two sorts of stuff, one to which the quantum mechanical superposition principle applies and one to which it doesn't apply. Quantum theory would describe only the first kind of stuff and measurements happen when one couples (somehow) the two sorts of stuffs.... Measurements happen when one couples a small quantum system to a large measurement apparatus. As sketched here, this dualistic idea, i.e., that there are two kinds of stuffs, is not yet a complete theory. First, because it doesn't tell how to recognize the two sorts of stuffs.... Second, because it doesn't tell how to couple these two kinds of stuffs. (pp. 1-2)

Gisin is describing the Copenhagen Interpretation perspective. Niels Bohr said that classical equipment is needed to make a measurement. This shows, he claims, that there is no way to ever know what is happening at the quantum level because, as human beings, we are fundamentally *classical* systems ourselves.

LoP Interpretation says that Bohr is wrong. As sentient human beings, we are actually *quantum* systems. And because we are quantum systems, our personal relationships offer us an insider's perspective on what is happening, giving us deep insights into the mystery of measurement.

A growing number of physicists now realize that Bohr's position is not acceptable. Quantum theory is not complete unless it can explain what it means to make a measurement. Fortunately, an explanation is now available that completes this picture. It is called the "Relativistic

Transactional Interpretation of Quantum Mechanics" (RTI) and was first introduced in 2013 by Ruth Kastner.

The good news is that Kastner's theory aligns fully with the LoP Interpretation. Kastner and I used different approaches to arrive at our conclusions, but our solutions align almost exactly. However, her theory is developed in much greater detail when it comes to modeling forces. She helped me fill in a lot of missing pieces (Marman, 2018, pp. 91-96). As a result, RTI gives us a rich model for *what* a wave-function collapse is and *how* it works. And LoP Interpretation, based on principles, adds intuitive explanations for *why* quantum objects behave this way and *why* wave-function collapse at the level of quantum particles is directly related to the purposeful actions of organisms.

Both RTI and LoP Interpretation say that, yes, there are two kinds of stuff, in a sense. Although few people would call them "stuff," as you will see.

First, there are pure quantum states, also known as wave functions, that exist as superposition possibilities. These states, however, are not things or stuff, they are just possibilities that influence the outcome. LoP Interpretation says that they are *personal relationship* possibilities.

RTI and LoP Interpretation (and Relational Quantum Mechanics) also agree on something most other interpretations have missed: Everything that happens at the quantum level starts as a two-way street. This is true because quantum behavior is all about relationships. Also, both RTI and LoP Interpretation also agree that everything happening at the pure quantum level is real but exists outside of what physicists call spacetime. LoP principles explain the reason for this: All quantum states exist only between those involved in relationships; that is why they do not exist objectively.

The second kind of "stuff" are wave-function-collapse events. These are actualities – the things we can see and touch. This is the stuff that makes up what physicists call spacetime, because each collapse event creates an absolute spacetime energy profile that looks the same to all observers.[3] Thus, wave-function-collapse events are matters of fact. They exist as third-person phenomena seen by outsiders. And, because each event includes a transaction of energy and momentum, they are measurable. This is why equipment, which is made from this same "stuff," can be used to measure these events. In other words, not only is the equipment involved in the wave collapse that it is measuring, the equipment is also composed of wave collapse events that make it possible to *point* to the result of the measurement.

Here is another important piece to this puzzle. Kastner explains it with this analogy: Everything visible and measurable, which means everything that exists in spacetime, is only the tip of an iceberg. It is visible because it is above the water. However, most of reality is hidden beneath the water in the form of pure quantum states because all of the particles that make up the visible, tangible world are also involved in relationships at the quantum level. A

[3] Einstein's theory of relativity tells us that the energy or momentum by itself, and the time interval of the event by itself, will each appear different to observers in different reference frames. But if we look at the full energy profile of the event that includes the spacetime interval between the emission and absorption, and the exchange in momentum or energy between the emitter and absorber, then all observers will see the same absolute quantity, regardless of their reference frames. (Kastner, 2015, p. 165-170)

simpler way of looking at this is that what we are describing here is not two kinds of stuff, but two kinds of relationships.

The quantum realm is a world of personal, private relationships that are invisible to outsiders. The spacetime universe is a realm of public events. This is why the outer world seems to exist as a reality of its own. It might seem as if we are merely observers when we use third-person lenses to study the objective world, but this isn't true because we are also involved in the world through relationships. As a result, we both influence and are influenced by the world.

Now, what we need to do is dive below the surface of the water to see what happens when a wave function collapses. Kastner's RTI will be our guide. But her interpretation is based on a long history of research by some of the most famous names in physics. They laid the foundation, and it is worth taking a look at this history to appreciate the key lessons learned.

In 1928, British physicist Paul Dirac developed the first complete wave equation for particles that carry an electrical charge, such as electrons and quarks. His solution is consistent with both quantum mechanics and Einstein's theory of special relativity. While studying the math, Dirac noticed something curious: the equation also suggested the existence of an oppositely charged particle for each electron and quark. Within a few years, the first anti-electron was discovered, confirming his prediction. (Dirac equation, 2023)

Years later, when Richard Feynman was looking at Dirac's equation, he noticed that the way it describes anti-matter particles can be interpreted in a new way. Instead of an *anti-electron* moving forward through time, the same equation could be treated as an *electron* moving backwards in time. This is now considered an accepted way of treating anti-matter, but it is rarely used because the idea of anything moving backwards in time seems too strange. However, it was this idea that led Feynman to a new discovery. (Kastner, 2020, p. 7)

Feynman worked with the famous physicist, John Archibald Wheeler, to develop a new way of looking at the electromagnetic force. Instead of just treating the emission of a photon as an event that exists by itself, they wondered if they should also include a wave function moving backwards in time from the absorption event. Dirac's equation suggested that this offers a more complete story for the exchange of electromagnetic energy. What they discovered was quite surprising: All of the waves that radiate out from the emitter are cancelled out by absorber waves, except for the path between the emitter and absorber, where the waves add together. This is now known as "Wheeler-Feynman Absorber Theory." (Wheeler and Feynman, 1945)

John Cramer, an American physicist, realized that Wheeler and Feynman's discovery suggested that the traditional Schrödinger equation used in quantum wave equations was missing the absorber side of the story. Based on this idea, Cramer reformulated the complete wave-equation theory and published it in 1986 as the *Transactional Interpretation of Quantum Mechanics*. (Cramer, 1986)

The Transactional Interpretation (TI) solves several big problems in quantum theory. First, it shows that a wave function collapses when there is an absorption of energy (Kastner and Cramer, 2018, p. 2). It also says that the emission and absorption of a photon needs to be treated as two events that are directly connected. This solves Schrödinger's famous Cat paradox. Let's see why.

Schrödinger proposed his paradox to show how ridiculous it is to suggest that observers decide the fate of measurements. If this is true, he asked, then what happens if we put a cat in a box with a radioactive isotope that spontaneously emits a decay particle? Quantum theory says that the isotope is in a superposition state of being both decayed and not decayed. Then, if there is a detector that detects the decay particle, and the detector triggers the release of poisonous gas into the box, there is no way of knowing if the cat is dead or alive until someone looks inside the box. Therefore, if a human observer is needed to make a wave function collapse, a cat should be in a superposition state of being both dead and alive until someone sees the cat.

While there are very few physicists who believe the cat could be both dead and alive at the same time or that the observer is the factor that causes a wave function to collapse, most cannot explain what does cause a collapse. TI gives us an answer. It says that the actual collapse occurs when the decay particle is absorbed, which is when it is detected. That moment is when the superposition state collapses. This gives us a clear explanation of measurement. And it is now easy to see that the cat is never in an actual state of being both alive and dead. It is always one *or* the other.

TI also explains what is known as Born's Rule, which is the formula for calculating probabilities in quantum theory. Physicists have a strange practice when dealing with quantum statistics: They square the results of the wave equation to calculate the probabilities. This is not normal. If we flip a coin, we have a 50% chance of getting heads. We do not square this number. Quantum probabilities are treated differently: you have to square the wave amplitude to know the odds. Max Born discovered this through experimentation because this was the only way he could make the statistics work. Why does the wave equation need to be squared? Before TI, no one could explain it. Kastner (2013) says:

> In most prevailing interpretations, the Born Rule is either simply assumed as part of the mathematical machinery...or it is given a pragmatic, 'for all practical purposes' account, which in my view, fails to do justice as the crucial link between theory and concrete experience. The Born Rule constitutes a deep mystery for all prevailing interpretations ...other than TI. (p. 35)

TI solves this problem because it shows that, in fact, there are two wave functions: both the emitter function and absorber function exist. We need to include the effects of both, and this means multiplying them together. And, because the two functions have the exact same wave profile and amplitude, you can take the amplitude of either one of them and square it.

Despite TI's ability to offer a number of significant advantages, it never became popular because it has one weird property: It suggests that absorber-wave functions travel backwards in time.

Independently of Cramer, the famous physicist, Paul Davies, developed a quantum level version of Wheeler-Feynman absorber theory. His solution is also compatible with relativity. (Kastner and Cramer, 2018, p. 1)

Kastner then used Davies' work to create a version of TI that is updated to be compatible with relativity, which she calls RTI (*Relativistic* Transactional Interpretation). Kastner's changes to TI also include a full quantum level interpretation, along with a number of other improvements.

For example, Wheeler and Feynman said that there is a *causal* emitter-wave function that carries energy and moves forward in time, along with a *reverse-causal* absorber function that also carries energy and travels backwards in time. But, Kastner's full quantum level interpretation shows that the emitter-wave function and absorber-wave function are *not* causal waves carrying energy because they are only possibilities. There is only one *causal wave that carries energy* and it moves only *forward* in time. This causal wave represents the creation of a real photon that travels from the emitter to the absorber. (Kastner and Cramer, 2018, pp. 3-4)

The second change introduced with RTI's model is that, before the emission of a real photon, there are time-symmetric fields going back and forth between the emitter and all of the possible absorbers. These wave functions are not quantized, and they do not carry energy because they represent the exchange of virtual photons, not real photons. And, **while this exchange of virtual photons carries no energy, it does, in fact, carry a real force.** (Kastner and Cramer, 2018, pp. 3 and 5)

The third change that Kastner discovered is that, while Wheeler and Feynman worked hard to make sure that "all emitted fields must be absorbed" in their theory, RTI says that no emission of energy is even possible unless there is an absorber response. Kastner (2017) says, "Physically, this means that the emitter and absorber mutually create the emitted field; both are required." (p. 10)

Also, RTI shows why the wave functions exchanged before a wave-function collapse do not actually travel through spacetime: They remain below the surface of the water in the invisible domain of quantum possibilities. Thus, the backwards-in-time problem disappears.

All of this fits exactly with the idea that the absorber-wave function describes the *possibility of absorption* and the effect this has on the emitter. **In other words, this is about anticipation. That is why information seems to travel backwards in time from the future event of absorption.** It does indeed influence what happens now, but it is only the *possibility* of absorption that influences the present. This influence acts as a true force that seems to reach across time and space, but it has no *direct* effect on spacetime because it carries no energy.

This is in line with LoP Interpretation that says these are *private* relationship possibilities that only affect those involved in the relationship. This is why these wave functions cannot be detected by outsiders. And this is why they never belong to the *public* world of spacetime.

With the RTI model, we can now explain the *where*, *when, and how* of measurement. Every measurement requires wave function collapse, and this means *absorption* of energy or momentum. This makes sense because we always need "detection" to gain the result of measurements.

If you think about it, we never actually see emission. We only see absorption, just like we only see photons when they hit our eye. We detect events only after the fact. The origin of those events is always in the past. But the process before a wave-function collapse is all about *anticipation* leading to *mutual agreement* between an emitter and absorber.

This exchange of wave functions between an emitter and possible absorbers before a collapse is now called "direct action" because the influence they have on each other leads to the creation of a real photon that travels directly from the emitter to one absorber. No other wave functions travel through spacetime. The only thing moving through spacetime is the photon carrying real energy and momentum, and this photon moves *directly* from the emitter to the absorber. Plus, this event is created by both the emitter and the absorber. In other words, we can treat this as a jointly made purposeful act because it only happens when both the emitter and absorber agree. Only after their agreement, which TI calls "a handshake," does the photon fly *directly* from the emitter to the absorber, with the absorber as the predetermined target.

This fits exactly with the *joint action* I described when two people decide to get married. This is what creates a wave-function collapse. However, this is not the way people usually think about purposeful action. The moment we decide to start running, we run. We only need to think about raising our hand, and it shoots up. However, it is a mistake to think that we ever act on our own. Our muscle cells do all the actual work. We act jointly with our body without even thinking about it. All of our purposeful deeds are, in fact, mutual agreements. The mind-body gap is bridged when we include relationships. The point here is that collapse events only emerge from relationship possibilities when those involved *agree to act together*.

There are some mind-boggling implications from all of this. Think about what it means when you see light from a distant star. You are receiving a photon that began its journey billions of light-years before. But the atom in the star that emitted that photon and the atom in our eye that absorbed the photon reached an agreement, or handshake, before the emission took place. What makes this harder to fathom is that, by the time we absorb its light, the star may no longer exist.

How can that be? It seems impossible from our perspective. But to the photon it makes perfect sense because, as Einstein's relativity shows, no time passes for the photon from the moment of emission to the moment it is absorbed. The reason for this is that clocks slow down when anyone travels at speeds approaching the speed of light. And this means that photon clocks stop completely because they travel *at* the speed of light. From the reference frame of the photon, in the public reality of spacetime, emission and absorption happen at the same time.

Kastner (2020) made another fascinating discovery. Wheeler and Feynman had to work hard to make sure all wave functions traveling through spacetime cancel out exactly, except for the one wave function that travels directly between the emitter and the absorber. This is important to make sure that the law of the conservation of energy is obeyed. RTI shows a much more elegant solution: All emitted energy is always absorbed because absorbers are equally involved in the creation of wave-function-collapse events. This is always true whenever energy or momentum is exchanged. **This is the real reason why the conservation of energy and the conservation of momentum act as if they are laws.** (pp. 8-9) In other words, these global conservation laws exist because all wave-collapse events are the result of two-way mutual agreements to act.

Earlier, I gave the example of how two people become good friends and get closer and closer. Up to that point, everything is just between them. But, as soon as they make the step to get married, the relationship changes. Their relationship then becomes real to the world. An exchange of energy is needed to make the marriage a public event. This is where it applies to the laws of conservation: Whenever one person in a marriage gets married, they both get married. When one publicly gives a ring, the other receives it. When we look at the whole event, the exchange is always conserved.

We now have a clear description of what happens when a wave function collapses. This solves the most vexing part of the measurement problem. Other theories ignore the importance of the absorber effect. They only see one side of the story, leaving anticipation out of their theories. **Once we add anticipation back in, it is clear that all wave-function-collapse events can be treated as purposeful acts.**

Kastner's model leaves only one piece of the measurement problem unresolved: *Why* does a photon land on one spot and not another? *How* is this selection made? What is it that causes an emitter to act jointly with one absorber and no other? Kastner answers these questions by saying that we do not know *why* because this is not a "causal process." It is not determined by outer forces alone because possibilities only *influence* the outcome. (Kastner and Cramer, 2018, p. 9)

However, Kastner (2016) goes on to offer an explanation that is well known to scientists: She says the wave-function-collapse process is the same as "spontaneous symmetry breaking," which describes a sudden shift that happens within a field (p. 16). Symmetry exists when a property is shared across a field. For example, there is a loose bond between water molecules floating in the air. When they are warm, molecules keep some distance between each other because they need space to vibrate. However, when the temperature drops, water molecules start feeling stronger bonds pulling them closer together.

Which molecules make this change first? Once again, it comes down to relationships. Some feel the urge to get closer before others. As soon as a few water molecules start bonding, the water-vapor field makes a phase change from gas to liquid, and droplets start falling from the air as rain. Crystals, such as salt, emerge out of a solution of brine in the same way. When symmetry in a field breaks, it happens *spontaneously* from *within* the field. A number of scientists say that both wave-function collapse and quantum symmetry breaking occur in the same way – they describe the same process. (Kastner, Kauffman, and Epperson, 2018, p. 5)

Here is an example that physicist Lee Smolin (2007) uses to describe symmetry breaking:

> Physicists…say that the symmetry between us at birth is broken by the situations we encounter and the choices we make. In some cases, it would be hard to predict the way the symmetry will be broken. We know that it must break, but looking at a nursery full of infants we are hard-pressed to predict how. In cases like this, physicists say that the symmetry is spontaneously broken. By this we mean that it is necessary that the symmetry break, but exactly how it breaks is highly contingent. This spontaneous symmetry breaking is the second great principle that underlies the Standard Model of particle physics.
>
> Here is another example from human life. As a faculty member, I've sometimes had occasion to go to receptions for new undergraduates. Watching them meet one another, it has occurred to me that over the next year some will become friends, others lovers, a few will even marry. At this first moment, when they encounter one another as strangers, there is a lot of symmetry in the room; many possible couples and bonds of friendship could be forged in this group. But of necessity the symmetry must be broken as the actual human relationships develop out of a much larger space of possible relationships. This, too, is an example of spontaneous symmetry breaking. (pp. 59-60)

As Smolin says: "the symmetry must be broken as the actual human relationships develop out of a much larger space of possible relationships." He is using the exact same language that I have been using to describe the influence of relationships. Relationship possibilities weigh on all of us. And now we can see why this sudden shift looks spontaneous to outsiders.

Symmetry breaks when two people agree to marry. This is a wave-function-collapse event. And when this happens there is a visible change that can be seen by outsiders. Marriage is a public event. Up to this point, most stages in the relationship were invisible to everyone but the lovers.

RTI does not show us *why* one possibility is chosen and not others, but LoP Interpretation helps us understand. Why do people agree to marry one person and not someone else? We know why because we have personally experienced the way relationships grow until they lead people to make this leap to the *purposeful act* of marriage. The biological perspective does, indeed, give us new and valuable insights into quantum mechanics.

This also solves the problem that bothered Einstein the most about quantum mechanics. He said, "God doesn't play dice with the universe," because he found it hard to accept the idea that the results of a wave-function collapse are just random. He felt there must be a reason why one result is chosen over others. Now we can see that he was right. There is a reason, and we can understand this reason because we experience the same thing every time we choose to act.

It is now clear that symmetry breaking and wave-function collapse, at the level of quanta, follow the same patterns that we see in human relationships when there are joint actions. And, because of friendships and marriages, we see new forms and patterns springing out of uniformly symmetric fields. Water drops and salt crystals emerge in the same way. In other words, visible forms are created by invisible relationships. Tangible events take shape from the intangible dynamics in relationships between sentient agents. Quantum mechanics finally makes sense because we are fundamentally quantum systems as well.

This gives us a rich, detailed way of describing the wave-function-collapse process at the quantum level, and it validates LoP theory because this is the same process we know so well at the human level. Therefore, it does make sense to say that a collapse event is the result of purposeful action.

Conclusions

Before ending Part 1 of this Opening Doors to a Quantum Theory of Life series, I would like to take a moment to point out something that has become clear from comparing the behavior of particles to the behavior of organisms. When most physicists use a term like "spontaneous symmetry breaking," there is generally a great deal of vagueness about what this term actually describes because *how* and *why* these events take place is hard to nail down. I believe this is a sign that we have been lacking the right lens to make sense of this significant principle that is fundamental to modern physics.

Smolin says above that symmetry breaking is "highly contingent." This does not go far enough. Analyzing every factor that influences the outcome will never tell us enough to determine how or when the symmetry will break. Yes, it is highly contingent because all of the influences are based on possibilities that are contextual. However, this will never give us enough to explain the end result. How is the choice made? Symmetry breaks are decided by personal relationships and the joint agreements that sentient agents make. The shift starts *between* them. Later it becomes public.

When we think about human relationships and how people make decisions to live together or get married, it is easy to understand these spontaneous changes because we know what it feels like to be on the inside of relationships. As a result, decisions made by two people together make far more sense to us than changes happening spontaneously between quanta. It is easier to see why relationships between people leap suddenly to a new phase.

This gives us an intuitive understanding of the wave-function-collapse process. It shows us how quanta make a shared choice, and this helps us relate to what happens from the inside out because it starts with relationships and the invisible exchanges that take place between them. The biological perspective *can* help us understand the bizarre behavior of quanta.

Relationships come down to the way sentient beings respond to each other. How else could a couple jointly decide to marry? *Both* must want the relationship to grow before they can leap into marriage. Invisible exchanges between them transform their relationship into commitments that eventually become visible to outsiders. This is what makes quantum behavior seem so strange, and it shows us how consciousness *is* involved in the equation. As Carlo Rovelli proposed, starting with principles, we can now say that we understand quantum mechanics intuitively.

But this approach to interpreting the behavior of quanta has taken us further. It also explains why fundamental particles display so many of the same characteristics as life. Whenever there is a spontaneous break in the symmetry of a relationship, we also see a change that leaps the relationship to a new state. This is how purposeful actions emerge.

Machines are designed to be controlled by outsiders. They do not originate behavior on their own. Living organisms are the opposite – they are organized to act on choices that emerge from within. When muscle cells get a message from our brain, they go through a phase change, like symmetry breaking, that causes the muscles to contract. This is how muscles move our bodies.

Mechanical forces are cause-and-effect reactions that take place in time. Quantum relationships act as influences that reach *across time* because anticipation of future possibilities affects the outcome. What *can* happen in relationships affects what *does* happen, and this also reaches *across space* because they emerge from mutually shared relationships. The moment possibilities collapse down to one choice, there is an exchange of real energy. These are no longer invisible exchanges taking place between them, they are objective events that become visible to the world.

We now have a scientific theory for anticipation and purposeful actions that shows us why these two quantum properties emerge wherever sentient agents form relationships, on every level. This explains why quantum effects *should* exist between organisms, far beyond the atomic realm. If this is validated with further testing, the scope of quantum biology has the potential to expand dramatically because it opens doors to a truly scientific theory of life.

It also shows why organisms are different from machines – because they initiate purposeful behavior from within through relationships, and because they anticipate the future before they act. These are two abilities that biologists say distinguish life from mechanical and chemical reactions. This is what makes it so surprising to find these same behaviors at the quantum level.

Biologists have other key traits that only life displays, such as the way organisms hunt for food to preserve their lives, and reproduction to create new life forms. Of course, human beings and animals have abilities that plants and single-celled organisms do not possess, such as the ability to use tools. Therefore, we should not expect to see all of the traits of organisms at the quantum level. I will discuss this in more detail in a future paper. But, as surprising as it might sound, if we take a closer look at what we learned in this paper, we can see that quanta *do* behave in ways that are similar to eating food to preserve life.

True, electrons and quarks do not actually consume food or eliminate wastes, per se, but as we learned in section 2.5.8, every time there is an exchange of energy, particles engage in absorption and emission. They absorb and emit energy. Yes, the comparison seems weak, at first glance, because emission comes before absorption, while eating comes before elimination. But, we now know that, before a particle can emit energy, another particle must agree to absorb that energy. This means that absorption holds the key place, just as it does with creatures searching for food. This becomes even clearer when we make a measurement; it is only the act of absorption that we see. Absorbing and consuming do seem to occupy the lead roles.

Does this mean that particles absorb and emit energy to preserve their lives? That sounds as if we are taking this comparison too far. However, our new interpretation offers two added facts that make this a closer match: First, for particles to exist *in spacetime* they must engage in an exchange of energy. We can't see or detect a particle unless it emits or absorbs energy. And this means that, to live in our objective world, it needs to *continue* exchanging energy.

Secondly, the uncertainty principle tells us that it is impossible for particles to stay in one place without moving because, as soon as their position is fixed, their momentum cannot be fixed at the same time. This ties back to what I said in section 2.5.7:

> Dead bodies don't push back. They settle into equilibrium with the environment. They do not oppose external forces. On the other hand, it is a fundamental trait of sentient agents to resist attempts that try to limit and control them. If this is right, then perhaps Heisenberg's uncertainty principle is *not* the source of free will. Perhaps the opposite is true: The need of quanta to act as sentient agents is the cause behind the uncertainty principle.

Do you remember how Schrödinger (2001) describes the characteristic feature of life?:

> When is a piece of matter said to be alive? When it goes on 'doing something', moving, exchanging material with its environment, and so forth, and that for a much longer period than we would expect an inanimate piece of matter to 'keep going' under similar circumstances. (p. 69)

Well, we see the same thing with quanta. It is impossible to keep a particle in one place. This is why particles continually emit or absorb energy. Therefore, it makes sense to say that particles need to engage in work in order to live in our spacetime world. Just like organisms.

What about reproduction? Clearly, we see no signs of electrons or quarks dividing to create offspring. But we do see something similar. Spontaneous symmetry breaking occurs when one field splits into two, and this always happens from within the field.

Many physicists think that the three forces described by quantum field theory – the weak force, the strong force, and electromagnetism – all originated as one field that split into three shortly after the Big Bang (Siegel, 2023, see "Evolution of Forces" illustration). This spontaneous splitting of fields is a core principle of the Standard Model of Particle Physics;

but, as I said above, it happens from within, not through outer forces alone. And when a field "breaks," a new field is created that is slightly different from the original.

For the same reason, we can say that the many types of particle fields, such as the electron particle field, the neutrino particle field, the up-quark particle field, and the down-quark field all emerged from one original particle field that split apart to create the different types of particles. In fact, in Part 2 of this series (Marman, 2023b, pp. 128-129), I give an example of why a single quark field may have split into two, creating down-quarks and up-quarks.

Spontaneous symmetry breaking *does* "give birth" to new fields through the process of division. Of course, this is *not* showing *particles* that are reproducing, it is fields that split. But this makes a lot of sense when talking about organisms, as well, because sentient agents *never* divide. It is their bodies that create a new form that separates when it becomes the body for a new sentient agent. I offer an explanation for how this might work in Part 2 (Marman, 2023b, section 10).

This shows how a theory based on principles *can* offer deeper insights into the mysteries of nature. However, there is a huge challenge that comes from a theory of principles, as Smolin points out (Smolin, 2017, p. 230): "Principle theories set out general principles whose universality requires that every particle and force in nature satisfies them." In our case, this means that all relationships between sentient agents must obey all of the LoP principles. This is what makes principle theories so hard to find. And this is why we must challenge and test these principles to make sure we are on the right track.

It is startling to see fundamental properties of life, like these, at the level of quanta. However, we are still a long way from explaining the functions of even the simplest organisms.

How do proteins, enzymes, and other chemicals come together to make a living cell? And how do our cells and organs come together to form a relationship so strong that human beings and animals are able to act as single sentient individuals? In other words, how do we, as individual beings, come to exist with bodies? And how do we, as beings, use top-down influence to cause our bodies to move when we want them to?

Part 2 of this ODQTL series (Marman, 2023b, section 10) answers these questions, and more, to open another crucial door for a theory of life.

Addendum: Deriving Quantum Formalism from LoP Principles

Now that we have an intuitive way of understanding superpositions and wave function collapse, we can show why quantum formalism finally makes sense. I will now go through the process of deriving all of the key elements of quantum formalism from LoP principles.[4]

> The only consensual part of the [quantum] theory is a formal skeleton enabling one to calculate the probability of various experimental outcomes at any time, given the initial preparation. This formal skeleton is often complemented with bits and pieces of former pictures of the world borrowed from classical physics, but connected to one another in

[4] I presented a version of this topic, deriving quantum formalism, in Marman, 2018, p. 108-118. This version has been edited and improved, to streamline the explanations and make it more suitable for this paper.

> an unfamiliar and unruly way. A recurring complaint is that, *as long as we are left without any truly coherent representation of the world and of its 'ontological furniture' compatible with the quantum formalism, we cannot claim that we truly 'understand' quantum mechanics.* [emphasis added] (Bitbol, 2010, pp. 54-55)

Based on the LoP principles presented in section 3, we now have a coherent representation that suggests why quantum formalism might take the form that it does. This means that we should be able to offer an explanation that describes quantum behavior in a way that makes intuitive sense. This also opens doors to a theory of life founded on these same principles.

Why is this science called quantum "mechanics" when there are no mechanical reactions – no clear cases of cause-and-effect at the quantum level? The reason is because one aspect of quantum mechanics (QM) is highly mechanical: quantum formalism itself. This is a mathematical process that physicists go through to determine statistical predictions. It has proven itself to be the central foundation of QM for physicists. No one has ever found a case where it has given a wrong answer. Any new interpretation or theory is tested by comparing it to this formalism.

Therefore, here are the questions that need to be answered: What is quantum formalism trying to tell us? What does it mean? Why does the natural world work this way?

> Regarding its formal structure we could say that quantum mechanics seems to be a 'finished theory.' In terms of empirical adequacy, it provides outstanding results, its mathematical structure – developed in the first three decades of the 20th century by people like Werner Heisenberg, Pascual Jordan, Max Born, Erwin Schrödinger and Paul Dirac – seems able to provide until now the adequate modeling to any experiment we can think of. However, apart from its fantastic accuracy, even today its physical interpretation remains an open problem. In the standard formulation, quantum mechanics assigns a quantum mechanical state to a system, but 'the state' has a meaning only in terms of the outcomes of the measurements performed and not in terms of 'something' which one can coherently relate to physical reality. It is not at all clear, apart from measurement outcomes, what is the referent of this quantum state, in particular, and of the formal structure, in general. If we are to ask too many questions, problems start to pop up and simple answers seem doomed to inconsistency. (Ronde, 2011, p. 9)

LoP Interpretation says that the main wall we hit in trying to understand quantum formalism comes from using *only* third-person lenses. Pure quantum states, such as superpositions, cannot be seen completely that way because they are not objective (see section 4.1). Therefore, the first thing quantum formalism seems to be telling us is that quantum reality is not built on an objective *foundation*. The visible and tangible world all around us is only the tip of an iceberg.

The real foundation, according to LoP Interpretation, is relationships. Pure quantum states display the same kind of dynamics that we see as personal relationship possibilities between living creatures (see section 4.1). This gives us a new way of picturing invisible quantum states.

From our own experiences, we know the influences that relationships have on us, and how unpredictable and irrational they can be. Relationship bonds that we form exist as mutually shared states. The possibilities shared between us and our partners are private. They are not visible to outsiders, not part of the public world; this is why they are not objective.

Why would we think that we can ever fully understand the mystery of friendships and romantic affairs by trying to study them only from an outsider perspective? The hidden part of the quantum world acts the same way, as if it is a participatory dimension that can only be seen by those who are involved. And the way we are involved is through personal relationships.

For the same reason, life cannot be understood by observing it from only the outside. As soon as we take an organism apart to study it, we kill life because life depends on relationships. This may be the message that quantum formalism is trying to tell us: The dynamic nature of quantum superposition states only exists when they are not being measured because they are private in their natural state. This makes sense if pure quantum states represent *personal relationship possibilities*. However, this suggests that fundamental particles may possess some form of sentience because personal relationships are only possible between sentient agents.

If this interpretation is right, then we *can* relate to everything that happens at the quantum level because we are also sentient agents involved in relationships. Therefore, an intuitive understanding *can* give us a true and accurate description of quantum states and why they behave so strangely.

Of course, particles possessing sentience will seem ridiculous to many, but we can set that aside for now because, when it comes to evaluating an interpretation of QM, all that matters is if it accurately represents all of the quantum formalism elements. If it does, the interpretation is deemed valid. Plus, as Bohr said earlier, (p. 13), all valid interpretations of QM *must* be truly *crazy* in some way.

Not only is it important to remember that the hidden dynamics in private relationships are *not objective*, they also should *not* be treated as if they are *purely subjective* perceptions because they are mutually shared states (see section 3). Therefore, they *do* have a reality of their own. We know this because relationships have such a powerful influence on our lives and the choices we make. Personal relationships are shared realities. This is why, as Heisenberg says earlier, quantum states stand halfway between *possibilities* and *objective reality*. Personal relationships create a bridge between subjective experiences and the objective world (see section 3).

The second thing quantum formalism is trying to tell us is that sometimes quantum states *do* become objective. This is what happens whenever we measure them: we always get *one* value that *is* objective. The measured result *is* a matter of fact that outside observers can agree on (see section 5.3). It is a mistake to think that quantum states never exist objectively or that they evolve in only a linear manner.

The point here is that private exchanges in personal relationships are only shared between those who are involved, but aspects of relationships do become public when they affect the world. This is what happens when the results of a personal and private relationship become objective. When this occurs, it creates a sudden change to the relationship that is both irreversible and non-linear. This is the wave collapse process. This shows that it is a natural product of relationships.

The purpose of this addendum is, at a minimum, to show that LoP Interpretation is consistent with quantum formalism, which validates the interpretation. However, this seems like too low of a bar. What is really needed is to show why the formalism takes the form that it does, starting from a set of basic principles (see section 3). Only then can quantum mechanics truly make sense.

This leads to the question about quantum formalism asked by Matías Graffigna (2016):

> The primordial question should no longer be "how does nature decide the result of a measurement given a superposition?", but, rather, "what is a superposition and what can it do besides being actualized in a measurement?" It is not that the process of actualization through measurement were irrelevant or unimportant for QM, but it seems that some previous knowledge is necessary in order to tackle it. We do not yet fully understand what a superposition is, but we do have the formalism, and also the possibility of grounding this understanding in a different ontology from the one of classical Newtonian mechanics. By taking the realm of possibility seriously…I believe we can start seeking for new physical concepts that allow the proper comprehension. (p. 25-26)

Yes, we need to take "the realm of possibility seriously," as Graffigna says. But we also need to realize that superpositions are not ordinary objective possibilities, they are *personal relationship possibilities* that shape relationships. Seeing what *might* happen in a relationship influences what *does* happen (see section 4). Possibilities are what give personal relationships a life of their own. Finding a lens that shows us what superpositions are is just one piece of the puzzle we need to solve. Many more questions are embedded in the formalism that also need to be answered.

There are several ways to present quantum formalism. They might seem quite different at first. However, eventually, they end up covering the same terrain. They pick different places to start and take different paths, but they end up tying all the same elements together. I am going to follow an approach laid out by Albert (1992) because he focuses on what he calls the "algorithm," the mechanical process that gives quantum formalism the name of "mechanics." He says, "It pretty much all boils down to five principles" (p. 30). These principles represent the foundation of the formalism. However, a fair amount of added discussion is needed to explain these principles.

Following are the five principles, each summarized in my own words from Albert (1992, pp. 30-36), followed by my explanations for why quantum formalism needs each of these five principles:

Principle 1: Quantum Superposition States

> *Quantum superposition states are represented by vectors called "state vectors." The state of every physical system is defined by a vector space that includes all of the possible states of the system, where each possible state corresponds to a vector and each vector has a length of 1 in that vector space. The vector space is complex (this means that both real and imaginary numbers are allowed). Each vector represents a quantum state, and all of the quantum states together represent the overall state of the system. Superpositions are represented by adding or subtracting state vectors using well-known vector math.*

Reading this shows us the mechanical nature of quantum formalism. It is a list of mathematical rules. But to see how truly bewildering it is, we need to dig deeper. Bowman (2008) raises these questions: What sort of information about a quantum system do quantum states represent? Is all of the information about a quantum system represented by its quantum states? And what exactly are quantum states? Then he adds that all these questions are still unresolved after 80 years of debate. (pp. 7-8)

However, physicists *do* know a lot about quantum states. For example, they know that they are not the same as states in classical physics. In classical physics, states represent the values of a system's properties, such as its mass, electrical charge, momentum, location, etc. The trajectory of a system can be measured in classical physics, and, based on the forces acting on it, the future path of that system can be predicted with great accuracy. Thus, a state in classical physics has numerical values that describe how fast the system is moving and the direction it is traveling, etc.

Quantum states, on the other hand, do not represent values. They represent *functions*. This means that quantum states cannot be represented by numbers alone because they influence each other. The point is not that quantum states change continually, because classical states also change. No, this is telling us that quantum states are *functions*. This is why physicists call them *wave functions*, not waves, because they are nothing like the material waves of an ocean.

To understand how abstract this idea of a quantum state is, look at how forces are represented by vectors in classical physics. The direction of the vector (where the arrow of the vector is aiming) represents the direction of the force. The magnitude of the force is represented by the length of the vector. This is easy to relate to. But what does a quantum state vector represent if it is a function?

Does the direction of a vector represent the direction of the function? No, not really, because it makes no sense to say that a function moves in a certain direction. Does the length of the vector represent the magnitude of the function? No, because in quantum formalism state vectors are all assigned a length of 1. Quantum states are abstractions that are so far removed from classical states that they are not the same at all. Except for one thing:

Quantum states do contain essential information about the system being measured.

The problem is that this information is contained in a function and physicists do not know what kind of function these quantum states describe. They cannot even agree on whether quantum states represent something real or if they are only mathematical tools.

However, the LoP principles that I outlined in section 3 lead to an explanation for what quantum superposition states are and why we treat them the way we do in quantum formalism: Pure quantum states represent *personal relationship possibilities between sentient agents*. This means that they are mutually *responsive* functions. Therefore, this first formalism principle is telling us that, when a *system* (usually an electron, photon, or other particle) is a *sentient agent*, all of the relationships the agent is involved with have an influence on that agent. This defines the complete quantum state of that system.

However, even though all possibilities in second-person relationships act as superpositions that influence a sentient agent at the same time, the reason you assign all vectors a length of 1 is because the strength of each possibility isn't important when it comes to how these quantum states combine to create the overall state of that agent. The only thing that matters is how superpositions from one relationship affect and interfere with the superpositions from other relationships because each possibility comes from a relationship that is *independent* of all the other relationships that are influencing the agent.

Only the *phases* between possibilities are important when it comes to how the possibilities in one relationship affect the possibilities in another. These phases act just like the phases of a wave that moves a cork floating in the ocean. The cork bobs up and down, forward and backward, as the wave passes by. Adding and subtracting vectors is an accurate way to represent the influence of these phases of superpositions because they are truly *independent* of each other. This needs some explaining.

Think about the example I gave earlier: Imagine a company offers you a new job that requires moving to another country. This would mean moving away from the person you just started dating. This illustrates how two *independent* relationships influence you: 1) the new job opportunity; and 2) the chance to get to know your friend better. Both weigh on you and your choices. Your job offer does not affect your friend *directly*, except in how it influences the choice you make. And your budding relationship has no *direct* effect on the company that is offering you the job – unless you decide it is more important to stay close to your new friend. These two possibilities exist in two independent relationships at the same time, as if they are superimposed over each other.

People might think that the job offer *is* having a *direct* impact on your budding relationship, but this is not actually true. Your friendship is not being threatened by the job offer. In fact, the company making the offer does not even know about your friend. These are simply two different relationships pulling you in two different directions. This is what happens at the quantum level.

Now, if your new friend wants to move with you to the other country, then the phases for these two relationships *align*. They reinforce each other. But, if your friend has other ties that keep him or her from moving with you, then the phases of your two relationships *interfere* with each other. All the relationship possibilities that influence you add to the complexity and so does their timing. This is why phases are a perfect way of representing how the possibilities in your relationships combine to create your overall quantum state before you decide what to do.

Also, personal relationships are represented by *complex* vectors, which means that they include both "imaginary" numbers, represented mathematically by $\sqrt{-1}$, and "real" numbers. This whole *complex* vector exists outside of spacetime, which tells us that it cannot be seen directly by outsiders. Superposition states do not belong to "the world out there" because they are not third-person realities, but privately shared states. Under Principle 5, we will see how these relationship possibilities transform into events that exist in spacetime. Spacetime is our reference frame for everything that happens in the objective public world.

To summarize our interpretation of the first principle of quantum formalism: All superposition states of a system that is a sentient agent are *relationship possibilities* that influence the agent. However, this, alone, does not capture all the information needed to determine the outcome of a measurement. As we will see below, under Principles 4 and 5, we also need first-person perception to explain how the outcome of a wave collapse is chosen. This is when the strength of a relationship possibility *is* important because *what is most important to us* makes a big difference when choosing which one of the possibilities we will act on with others.

However, looking only at relationship possibilities and how these superpositions combine to define the overall quantum state of a quantum system before measurement, which this first principle of quantum formalism is describing, we can represent the state of a system (that is a sentient agent) by using a vector space that is made up of all the relationship possibilities, with each possibility needing an independent dimension of its own, and where each vector has a length of 1. This describes exactly the special type of vector space that physicists use, called

"Hilbert space." Hilbert space is an *n*-dimensional vector space, where "*n*" represents each of the independent quantum possibilities. All of the relationship states of a sentient agent can be represented as dimensions that are orthogonal to each other, just like *x*, *y*, and *z* dimensions of 3-dimensional space are at right angles to each other, because all of the superpositions represent possibilities that involve the agent from *independent* and *private* relationships.

Principle 2: Observables: Measurable Properties

The measurable properties of a system, called "observables," are represented by linear operators that act on the vector space that is associated with the system. If a vector that represents a quantum state happens to be an "eigenvector" of an operator associated with a particular observable, and that eigenvector has an "eigenvalue" of "a," then the state is said to be an "eigenstate" of that observable. And, in this case, if a measurement is made, that state will have the value "a" for that observable.

Once again, we see this principle being described as a mathematical process. It says that only some properties can be measured. Quantum states are only *observable* if they form a relationship that can lead to an exchange of energy with the measuring equipment that is measuring them.

This second principle also tells us that if a quantum state has already formed a relationship that aligns with the measuring equipment before the measurement starts, then the value of that quantum state will not change when it is measured. This sounds like a strange thing to say. It sounds strange because physicists are not sure why this step in the process is necessary or what it is telling us. But the principle is easy to illustrate.

It turns out that this principle applies to a very special case. For example, if you measure the *spin* of an electron, and the spin state of that electron happens to be aligned to the *"z"* axis, and the measuring equipment is also aligned to the *"z"* axis, then – if the electron was in a "spin up" state before the measurement – it will produce a "spin up" result when it is measured.

This is a special case, but an important one. Why is it so special? Because we hardly ever know the state of an electron before we measure it. And if it is not *exactly* aligned to the axis that is being measured, then there is no way to know exactly what the result will be. That is when we need to refer to Principle 4, below. There is only one way we can know what the state is, and that is by measuring it. Therefore, Principle 2 is saying that we can know for sure what a result will be *only* if we just measured it immediately before we measure it again.

What does this principle tell us? Imagine a two-slit experiment. The value measured is indicated by the spot on the screen where a photon lands. The result is determined by the one absorber that is selected out of all the absorber options. According to LoP principles, the only relationship that can be selected is one where the wave functions of both the emitter and absorber have perfectly aligned their states with each other. RTI calls this process of alignment a "handshake." This means that, in order to create an exchange of energy, the wave function shared by the emitter and absorber must match exactly. In other words, they must become entangled by sharing the same state. And an exchange of energy is needed to measure that state. That is why this second principle of quantum formalism makes sense.

To explain this using formalism terms, a quantum state must match the state of the "operator" (the measuring equipment) to be measurable. This means that the system being measured must have a state vector that points in the same direction (or the exact opposite direction). This makes sense because we know that an emitter/absorber pair must share the exact same wave function before they can exchange energy, and an exchange of energy is needed to make a measurement (see section 5.3). The process of aligning and matching the states happens *outside* of spacetime because this is the dance between sentient agents forming a personal relationship with each other. On the other hand, measurement requires an exchange of energy *in* spacetime. We will explore this further under Principle 5.

The reason this special case is important is because it shows us that the *only* time we can ever know beforehand what the result of a measurement will be is when we have measured that same quantum state just before we measure it again. This shows that quantum states *do* represent an aspect of physical reality before they are measured, even though they cannot be seen by outsiders until they are measured (when they exchange energy).

When a quantum system being measured shares the state of an operator (the equipment designed to measure a specific observable, like spin), then that quantum state is said to be an "eigenstate" of that observable. This is just a fancy way of saying that the quantum state has a vector that is aligned with the same exact direction (or in exactly the opposite direction) as the equipment.

Principle 3: Wave Function Dynamics

Each quantum state changes and develops in a deterministic way, based on the forces and constraints acting on that state. There is a way to calculate what state that system will be in at a later time. The deterministic law that governs how a quantum state changes with time is represented by the Schrödinger equation. Since every state vector must, by definition, have a length of 1, and must remain a length of 1 as they change over time, the changes in state vectors dictated by the dynamical law are exclusively changes of direction, never of length. Thus, quantum states only change in a linear manner. This means that superposition states remain as superposition states as they change over time.

Note: Using the Schrödinger equation applies only to non-relativistic quantum theory because it only represents the emitter's side of the story. The role of absorber is ignored. Also, it does not account for the way quantum states can be created and annihilated, such as when a photon is emitted from an atom and absorbed by another atom. That photon is not sitting there buzzing around inside the atom before it is emitted. The photon is actually created to carry energy to the absorber, where it vanishes once it is absorbed.

What this third principle is telling us is that quantum states evolve and change over time as they interact with each other, but they do so only in a linear manner. This means that quantum states on their own cannot change in sudden or discontinuous ways. The creation and annihilation of quantum states are clearly cases of discontinuous change, so this third principle is only telling us what happens to quantum states when measurement is *not* involved and there is *no* exchange of energy. In other words, this principle only applies to the way *coherent* quantum states change when they are not being "observed" by outsiders. Why do wave functions act this way?

If quantum states are relationship possibilities between sentient agents, then this makes sense because relationship possibilities have a *direct influence* only on the agents who are involved. The only affect that quantum states have on other quantum states is by how their phases add or subtract.

Think about friendships you have with people you met in college. They have no *direct* effect on your relationships with your son or daughter because the relationship possibilities that you share with your children exist between you and them. In other words, your relationship with them is *independent* of your relationships with your college friends. This makes sense. And it explains why, when superposition states interact with each other, they cannot create non-linear changes. Stresses from the world can affect our family, but we can always retain our family bond if everyone in the family agrees to make their family bond more important. This means that outside influences cannot directly impact a relationship unless the people involved in the relationship allow it.

This principle also tells us that if only superposition states exist, they should never disappear. They should exist forever. This is why the Many Worlds Interpretation says that every possibility continues to exist in a different universe. As I showed in section 4.1, there are fatal flaws that have been discovered with any theory that says superposition states only change linearly. However, this problem goes away with LoP Interpretation and Kastner's RTI. Superposition states, just like relationship possibilities, can be created, and they can come to an end, as we will see with Principle 5, below.

It is also worth mentioning that the Schrödinger wave function describes quantum states being spread out across space. For example, the wave function can represent the probabilities of where a system will be located over time. The question remains, however, what is this "function" that is "waving"? Or, is it purely a mathematical tool? As Bernstein (2009) tells us, this is a question that bothered physicist John Bell for most of his life:

> What is the Schrödinger wave function? The standard interpretation tells us that the wave function provides information about a quantum mechanical system, such as the probability that, when measured, "observables" have some particular value. But is this all we have – "information"? Isn't there something else behind the scenes? Bell used to conjecture that – while physicists, when they teach or even use the quantum theory, seem to accept the idea that all we have is information – in their heart of hearts they really believe that the wave function is not the whole story. The information contained in it refers to something else, something not revealed – a hidden reality. (pp. 144-145)

The LoP Interpretation says that this hidden reality is composed of relationship possibilities. That is what the wave functions are. These possibilities change continuously, just like waves, from the back-and-forth invisible exchanges between those in a relationship. The possibilities change linearly because they change only when those involved in the relationship change their perceptions of each other. When we see new possibilities with our partner, this also changes our partner and the possibilities that they see with us. This is how relationships evolve.

This third principle gives us an important description of how *relationship possibilities* change over time when no outside measurement is taking place.

Principle 4: Measured Values and Born's Rule

> *If a quantum state is not an "eigenstate" of the operator of an associated observable being measured (see Principle 2 above), then, according to quantum mechanics, the*

outcome of such a measurement is a matter of probability. Born's Rule stipulates that the probability of each measurement outcome will be the absolute square ($|a|^2$), if the value of that state is "a." Also, any state that has a value of "-a" (which means the vector points in exactly the opposite direction with the same length) will have precisely the same measurable outcome because $|a|^2 = |-a|^2$. Therefore, any vector with a value of "a" is considered precisely the same physical state as a vector with a value of "-a." All measured values must be real numbers, and all eigenstate vectors of an observable must be orthogonal (at right angles) to each other.

In the second principle, we saw what happens when a quantum state already matches with the measuring equipment before the measurement takes place. The quantum state is then said to be an eigenstate of the operator (this simply means its state vector matches the direction and value of the state vector of the measuring equipment because they are entangled).

As I said, this is a very special case because it only really applies when the same measurement was performed shortly before. Is there any other way of knowing if a quantum state is aligned with the operator before it is measured? The answer is no. Then what happens if no measurement was made previously? Then principle 4 tells us how to proceed.

This fourth principle simply states that we must use Born's Rule (square the absolute value of a given quantum state) to find the probability of that state becoming the result of the measurement. Born's Rule is stated as a postulate. No reason is given for why we should proceed like this. But, as we saw in section 5.3, RTI clearly explains why we square the value. It must be squared because both the emitter wave function and the absorber wave function need to perfectly match before energy can be exchanged. This is why we need to multiply them. It makes sense.

This fourth principle also tells us that the "value" of a quantum state is directly related to the likelihood of it being selected. According to LoP principles, this value represents the "level of interest" that agents share with each other about a specific relationship possibility. This makes sense because level of interest is directly related to the choices made by sentient agents. And, just as with probabilities, level of interest is always a positive factor.

This principle also says that any quantum state with a value of *a* is the same quantum state if it has a value of *-a*. This also makes sense because when we use the relativistic model that includes both the story of the emitter and the absorber, we see that handshakes are only possible when both share exactly the same wave function, except one appears to move forward in time while the other acts like anticipation, moving backward in time, because future possibilities influence the present. This is why, when vectors are pointing in opposite directions, they represent the same state.

This principle also says that all measured values must be *real* numbers. This is exactly how it must be, according to LoP principles, because all measurements are the result of a wave collapse, and a wave collapse is all about the exchange of energy and momentum in spacetime. Spacetime represents the third-person reality of our universe. It is objective. It is also impersonal. This means that that the objective world has no imaginary dimensions because imaginary dimensions are only needed for shared states in private relationships that are hidden to outsiders. In other words, objective reality is a third-person state with no private relationships. This is why measured values must be real numbers. Thus, quantum states become objective when they are measured.

The last point raised by this fourth principle is that all eigenstate vectors of an operator associated with an observable must be at right angles to each other. The reason for this, as I said before, is that relationship possibilities are *independent* of each other. The relationship possibilities you share with a friend belong only to the two of you. This is how friendship works.

Principle 5: Wave Function Collapse

> *Measuring an observable changes the state vector of a system being tested, collapsing it or making it jump from whatever state it was in before into an eigenvector of the measured observable operator. Which eigenvector is selected is determined by the probabilities outlined in the fourth principle (Principle 4) above. It is at this point, and no other point than this, that an element of pure chance enters into the evolution of the state vector. Once a measurement is carried out, the state of the measured system must guarantee that if that measurement is repeated immediately afterwards, the same result will be obtained.*

We now come to the act of measurement itself. This not only applies to experiments with human observers but to every exchange of energy – to every actualized event visible in spacetime.

This last principle of quantum formalism tells us that the overall state of the system being measured, which includes all of the relationship possibilities that are influencing it, goes through a discontinuous change when it is measured. This is sometimes called a wave function "collapse" because the many other possibilities no longer exist, or it can be called a "jump" in the state.

The Copenhagen Interpretation, which is the most widely accepted interpretation of quantum mechanics, says that this is an element of pure chance because it reflects the statistical nature of reality. In other words, the reason one quantum state is selected over all the other possible states is based purely on chance alone. This is the point that Einstein refused to accept. Einstein has been criticized over his comment that "God does not play with dice," because many physicists think that he was unable to give up the old idea of classical physics. But that was not his objection. Born (1971) gives us Einstein's actual words:

> Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the 'old one.' I, at any rate, am convinced that He is not playing at dice. (p. 91) (For a deeper understanding of Einstein's words, see Livio, 2018.)

If you cannot explain how a possibility is selected, then saying that quantum formalism is telling us that we live in a probabilistic world adds nothing. This is the point that I think Einstein was getting at. Quantum formalism does not tell us *why* probabilities govern the result of measurements in a statistical manner because the process that selects the outcome is hidden from third-person eyes. And if scientific equipment cannot see *what* is happening, then quantum formalism, which is nothing more than a formalism based on measurement results, tells us nothing about *why* or even *how* outcomes follow probabilistic laws.

LoP Interpretation, with Kastner's RTI, offers both an explanation for *why* and a clear description of exactly *what* happens when a wave function collapses: One of the many relationship possibilities is selected to exchange energy.

How do couples decide to get married? In cultures where the choice is theirs, it is not an outside force that makes them tie the knot. It is a joint decision. Of course, families do have an influence. And it is often surprising to see who gets married. Some people meet and take the leap on the spur of the moment. Clearly, those with the strongest interest in each other are more likely to marry.

Yes, statistically we can say that getting married follows their level of interest, but the fact is that we cannot know who a person will marry or if they will marry at all. Even *they* do not know because relationships are not simply the result of probability statistics. Relationship possibilities are inscrutable. No one can determine the outcome for a couple. It is not predictable. But this does not mean the result is merely a matter of chance. **Marriage is a meaningful selection. It is intentional. It is done for a purpose.**

And the moment a person marries, all the other possible marriage opportunities vanish. Those possibilities disappear. Our lives change when we get married, and they immediately start evolving and changing based on a completely new set of possibilities. Thus, this fifth principle of quantum formalism makes sense, based on LoP principles.

In section 5.3, we showed the process of what happens during a wave collapse. It begins when an emitter negotiates with potential absorbers. This happens outside of spacetime. The possibilities of an exchange in energy are passed back and forth until an emitter-absorber match is made. The quantum states (that are related to the exchange of energy) for the emitter and absorber then become so closely aligned that they become entangled and share the same state. They share the same exact wave function, although the emitter seems to proceed forward in time, while the absorber's influence seems to proceed backward, as it joins with the emitter to accept the emission.

Let's now translate this to the measurement of an electron's spin state. If the electron's spin state is not aligned to exactly the same spin axis that the equipment is measuring, then the electron must align its spin state to match the equipment before it can exchange energy.

Why does the electron adapt and not the equipment? Because the detector is made from millions of particles that are all aligned to the spin axis being measured. Clearly the lone electron needs to be the one that adapts, not all the millions of atoms in the equipment.

Remember this is the result of a relationship that forms between the electron and the equipment. And the equipment has already aligned to the objective reality of spacetime for the same reason, because all of its atoms are continually involved in exchanges of energy with the world around it. This is why the final measured value of an electron spin state is always a real number, not a complex number, and it always matches the spin axis of the measurement equipment. This is what happens when a pure quantum state interacts with a detector that is an objective measuring device.

The last point stated in this principle is that, if you measure the system again, immediately after a measurement is made, you must get the same result. I explained why this happens under the second principle. But putting it here as part of the fifth principle also makes sense because it tells us that all the other possibilities truly do vanish when the wave function collapses. They disappear. This is why, if you immediately measure it again, it must give you the same result. It must be the same because there are no other possibilities around to change the state.

Over time, new possibilities will emerge, but, after a major change, it takes time to see new possibilities. If you graduate from high school or college, or you join the military, or retire, or if you are a teenager going through puberty, many of the options and possibilities in your life change. But it takes time to see the new possibilities clearly; to see how they relate to your new life. This also makes sense.

By using two new interpretations of quantum mechanics, RTI and LoP, we found an intuitive way to understand quantum formalism, and we learned why quantum formalism takes the form that it does. This understanding paints a new picture of the natural world. It suggests that we live in a universe where everything happening is affected by relationship dynamics that are hidden and intangible to outsiders because relationship possibilities are not objective. The personal dynamics are private. They don't exist in the public world of spacetime, but they are real. And we know they are real because they influence everything that happens.

As I said in the Introduction of this paper (p. 12), "The discovery of quantum mechanics pulled the rug out from under the main ideas of classical physics, such as cause-and-effect, forces, matter, space, and time. That foundation is now gone in quantum theory, with no clear understanding about what is truly fundamental." Our new interpretation of QM offers a possibility that is well-suited to biology: Sentience and the relationships that form between sentient beings might be the foundation we have been looking for.

However, one more crucial piece to the puzzle is needed to explain how life works. See Part 2 in this ODQTL series for the completion of this new theory of life.

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relationships. Using Alan's lens has given me a much richer understanding of biology from an inside-out perspective. Here is a website, created by some of Alan's friends, that offers a great introduction to the world of natural inclusion: https://occurrity.com/

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Note: All urls in this reference list are live links.

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