Opening Doors to a Quantum Theory of Life, Part 2: Top-Down Causation

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Abstract: In Part 1 of this series, "Opening Doors to a Quantum Theory of Life" (ODQTL) (Marman, 2023a), we saw that Niels Bohr, Erwin Schrödinger, and Werner Heisenberg were some of the first to raise hopes that discoveries in quantum mechanics might solve biology's hardest problem: explaining how life works. However, they hit a wall. In fact, they hit a similar wall when they tried to make sense of quantum mechanics. We found that two recent interpretations of quantum mechanics open some new doors to both the mystery of life and to an intuitive understanding of quantum mechanics.

Surprising signs of life at the quantum level were reviewed in Part 1, as well as unexpected signs of quantum behavior in relationships between organisms. A detailed analysis showed that quantum states display the same properties as what biologists call "anticipation" when future possibilities in *superposition* states influence the end results. And a quantum *wave function collapse* displays an act when a selection is made, showing the same properties as what biologists call "purposeful action." We then saw how, starting with four principles, it is possible to derive all of quantum formalism. This suggests a new possibility: Sentience and relationships between sentient agents may be the true foundation of quantum mechanics. This also makes sense as a foundation for biology.

This paper, Part 2 of this ODQTL series, proposes a quantum theory of life that shows how cellular life could have emerged from quantum processes. A new model for life's origin, called the Catalyst-First Hypothesis, is offered that shows why catalysts might be the real drivers of the origins of life: because catalysts engage properties of top-down causation.

The new theory described in this series of papers suggests that life is not based on the right combination of ingredients; it is a *mutually responsive relationship* between a life form and its living habitat. We cannot take this relationship apart to study life because taking it apart ends the relationship. Interpretations of quantum mechanics can explain this irreducible property as entanglement. And a new interpretation explains why we *should* see quantum principles like entanglement in relationships between organisms. And this all leads to the *complexity* at the heart of life that emerges from top-down causation in nested relationships.

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Introduction

Before we turn to explaining the most mysterious property of life, it is worth taking a few moments to review what we learned in Part 1 of this ODQTL series (Marman, 2023a). We discovered that quantum particles in a *superposition* state, when they are not being measured, exist in a state where all of their relationship possibilities have an influence on what happens next. In this state, future possibilities affect the choice that quanta make when the *wave function collapses* down to one result. We saw that this matches precisely a process that is considered unique to life, when living organisms, even those without brains, first enter a state of *anticipation*, where future possibilities are weighed before engaging in *purposeful action*.

The Lenses of Perception Interpretation of Quantum Mechanics (LoP Interpretation) (Marman, 2018) is founded on a postulate that quanta are sentient. As I showed in the Addendum to Part 1, by starting with four principles, we can derive the formalism of quantum mechanics and explain why it takes the form that it does, validating this interpretation. The LoP Interpretation accomplishes this by, first, explaining what superposition quantum states *are:* They are *relationship possibilities* between sentient agents.

Physicists and chemists have overlooked the role of personal relationship dynamics and how *possibilities* keep personal relationships alive. Possibilities are a source of creativity that gives life forms the ability to originate behavior. Organisms are not like machines; that is, life forms are not driven by only outer forces. Their relationship possibilities also play a key role in the uncertainties and complexities of life. And relationships that we, as sentient beings, have with our cells and organs lead to a natural way of bridging the apparent gap at the heart of the mind-body problem.

There are over a dozen valid interpretations of quantum mechanics but only one that predicts rudimentary properties of life at the quantum level, suggesting that life may not be something that emerges out of a soup of chemicals through a mythical bolt of lightning because life has been there from the beginning. It also leads to the surprising prediction that quantum behaviors should also exist in all relationships between organisms because they are sentient as well. In other words, we can see the superposition properties of quantum states in the relationships between life forms.

In the Conclusions of Part 1, we saw that quanta display a number of similarities that are unique to life, including how organisms search for food to preserve their lives and reproduction.

However, we still face a huge gap because the behavior of quanta is so elementary. Quanta show no signs of thought. If they are acting with a purpose when they commit to a possibility, it seems more like an opportunistic, subconscious urge. Quanta appear to behave instinctively, with a bit of free will that shows up as a level of uncertainty that can never be eliminated.

This still leaves us a long way from understanding the origins of life. Even the simplest living cells display a flow of life so complex that it seems incomprehensible. How could the opportunistic behavior of quanta evolve into a group of complex molecules teeming with life in a living cell? How can subconscious reactions of sentient quanta lead to the development of DNA as the key to the long-term survival of species? We are still far from solving the full mystery of life that we want to understand.

Remarkably, one simple property of life offers a path to explaining all of these missing pieces.

1. The Nested Relationships of Life

One of the most remarkable displays of life forms is their nested organization. We see complex molecules, such as proteins and enzymes, working together to form living cells that are able to act as individuals. These cells then create receptive-responsive working relations with each other to make multicellular organisms from groups of cells that specialize as tissues, bones, nerves, heart, lungs. And these organs work so closely together that creatures can act as individuals. These same multicellular individuals then gather to form families, colonies, societies, and swarms of species, which then combine with other species to create complex communities, ecosystems and biomes that thrive on the diversity of their members.

In the case of social insects, such as bees and ants, their colonies seem to act almost as individuals with a consciousness of their own. When a beehive is attacked, bees respond immediately as if they belong to a larger organism.

Cellular slime molds are single-celled organisms that can come together to form an individual slug-like body when food is scarce. When it is time to reproduce, some of the cells die to form stalks of fruiting bodies capped by spore-masses. And other cells die to kill off attacking bacteria. (Zimmer, 2011, p. 1) In other words, they act as if they are multicellular creatures that share a brain, but they are not. They are single cells with no brain. They simply come together to work as a group for a while, for a particular purpose. Another type of slime mold even solves puzzles as a shared effort without a brain, such as finding a path through a maze. (Jabr, 2012)

Cellular slime molds have a unique feature that makes them different from bacteria, which are also single-celled: Slime molds have mitochondria living within them. Mitochondria have their own DNA, but they work so closely with the DNA of slime-mold cells that mitochondria can no longer live on their own outside of cells. In other words, slime-mold cells have this same pattern of nested individuals working together within them. In fact, all multicellular animals, plants, and fungi include mitochondria in their cells.

Here is another amazing trait of biological life that, at first, does not seem related to the nested patterns of life but is actually the same principle at work: All living creatures depend on organic or mineral nutrients from the byproducts of other life forms. Even the simplest creatures, such as bacteria, need to extract nutrients from the waste of other organisms. What this shows us is not a food pyramid with predators at the top and bacteria at the bottom. We see a cycle of consumption that is circular. As a result, if you pull any life form out of its living habitat, it dies.

We see the same results with DNA, RNA, and proteins in living cells. Move those molecules outside of cells and they no longer behave as if they are alive. (Lyon, 2011, p. 112) On their own, they act like mere chemicals. This suggests that cells are ecosystems that are themselves alive and, somehow, these ecosystems act as a source of life. In other words, DNA, RNA, and enzymes only spring into the flow of life when they are inside a dedicated environment that is also alive.

Understanding this circular relationship between life forms and their environment is crucial to seeing how life works. This trait may be the single most important key to unlocking the mystery of life. And what better way to see how it works than at the level we know best: in our own living habitats that we call families, companies, countries, and communities.

Watching complex proteins act as if they are alive when inside living cells seems mysterious because we cannot see what drives them to perform such incredible feats. However, we understand what it feels like to live in a family and to work for an organization. Let's start with what we know from our own experiences.

What we are looking for with this exercise is, first, to find a lens that helps us see how life works from the inside-out and, second, to understand the principle behind the nested relationships of life. In other words, what makes families, companies, countries, and communities feel alive? Answering this may also tell us how to make our families and organizations healthier.

As I will show, the health of organizations seems to be directly related to their flow of life. The same is true for the health of organisms. Our health seems to depend on how well we work with the cells that make up our bodies on the inside and how we work with sentient beings that make up our living habitats on the outside. Nested relationships appear to play a central role in health.

We will start by finding a lens that shows how life works in organizations. Then, we need to find how this applies to organisms. And last, since this is all based on quantum principles, we need to understand how this emerges from the quantum level. This is how, starting with principles, we can find a theory for life. Once we have a lens that makes sense, we then need to formulate a model that is clear enough that it can be tested.

1.1. Working for a Company We Love

We know that some classrooms feel more alive than others. Some companies offer inspiring working environments, and some families seem to get along better than others. But what is it that makes these classrooms, companies, and families healthier?

We need to understand why students feel inspired to learn in some classes but not others. How does that happen? Here is a possibility: Good teachers can breathe life into a subject. If a teacher truly loves a subject, students can become infected with that love. This transforms the class. The added energy that flows in such a class invites everyone to join in, making the class more alive.

We see the same thing in companies. A good leader can turn working together as a team into an enlivening experience. If everyone on the team listens to and respects the leader and each other, work flows more smoothly and feels more rewarding. We look forward to getting up each day when we work at a company like that because we feel an empowering flow of energy. We do not feel worn out by such work. We feel energized.

Every family has its ups and downs. But some families have more time when everyone seems to align with and complement each other, like puzzle pieces that fit together. Such families spend more time encouraging each other than criticizing. And even though family members are usually very different from each other, those differences can lead to the family feeling closer to each other. This is what happens when everyone learns to appreciate and respect their differences.

Most of us have experienced inspirational classes, companies, and special moments with our families. But it is harder to duplicate these experiences than we think. When a family tries to repeat an activity that everyone liked doing together, it often seems less alive the second time around. This suggests that it is not *what we do* that creates the added flow of energy that we experience. Then what is it? How does this work?

Fortunately, there has been considerable research over the last fifty years into the best ways to make organizations more effective. It is now well-known that a boss who tries to "manage" his team by telling his subordinates what to do is not nearly as effective as the person who leads, inspires, and coaches his or her team to work toward a vision that everyone shares. This is why leadership training is recognized as an important step in building organizations that inspire us.

There are dozens of approaches to leadership training. However, I am going to focus on one that stands out because of how closely it aligns with the nested quality of life that we are trying to understand. We will then use this lens to find a pattern of life that has been hiding in plain sight.

1.2. Servant Leadership

Robert Greenleaf published his first book, *Servant Leadership*, in 1977. He wrote the book after decades of developing and training leaders at AT&T, which was one of the largest corporations in the world at the time. After retiring from AT&T, he reached out to help organizations of all sizes and types, including public institutions, non-profit organizations, and educational foundations. He saw the same problems in developing leadership wherever he went. He proposed a simple way to teach leadership by boiling down the requirements to their essence.

According to Greenleaf (1977), the first step to becoming a great leader is the desire to serve others. He discovered that all of the best leaders see themselves first as servants:

> The servant-leader is servant first.... It begins with the natural feeling that one wants to serve, to serve first. Then conscious choice brings one to aspire to lead. That person is sharply different from one who is leader first, perhaps because of the need to assuage an unusual power drive or to acquire material possessions.... The leader-first and the servant-first are two extreme types. Between them there are shadings and blends that are part of the infinite variety of human nature.
>
> The difference manifests itself in the care taken by the servant-first to make sure that other people's highest priority needs are being served. The best test, and difficult to administer, is: Do they, while being served, become healthier, wiser, freer, more autonomous, more likely themselves to become servants? (pp. 13-14)

Greenleaf is saying that leaders who serve others first not only build stronger organizations, they also increase the *health* of people and their sense of freedom and individuality. After decades of training those who became the best leaders, Greenleaf discovered that those who wanted to serve first were best at inspiring people to work for a common purpose. However, the idea that leaders should act as servants seems paradoxical. Don't leaders belong in the upper echelons of organizations, while servants belong at the bottom?

It is a mistake to see everyone at the top of an organization as *leaders* of that organization. They might be executives, directors, or managers of a corporation, but leaders, according to Greenleaf, are those who do not work to advance themselves first but to serve and advance the spirit of the whole organization. As a result, the healthiest organizations find leaders at every level. These are people who breathe life into our companies, families, institutions, and countries. Great leaders inspire *everyone* to become leaders. We see the same thing with democracies: they thrive only when most citizens feel and act with a sense of responsibility to their country.

Greenleaf (1998) then describes the second key requirement for leaders:

> An indispensable condition for the persuasive power [of leaders] to be effective is that the institution is living out a great dream.... Institutions function better when the idea, the dream, is to the fore, and the person, the leader is seen as servant of the idea. It is not 'I,' the ultimate leader, that is moving this institution to greatness; it is the dream, the great idea. 'I' am subordinate to the idea. 'I' am a servant of the idea along with everyone else who is involved in the effort.... It is the idea that unites people in the common effort, not the charisma of the leader.... Far too many of our contemporary institutions do not have an adequate dream, an imaginative concept that will raise people's sights close to where they have the potential to be…that has the energy to lift people out of their moribund ways to a level of being and relating from which the future can be faced with more hope than most of us can summon today....
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> A critical aspect of leadership, whether in a university in which a substantial piece of the power to govern has been ceded to faculties, or in business in which, structurally at least, all the ultimate power usually resides with the chief executive, or something in between, is this: Can the key leader accept that optimal performance rests, among other things, on the existence of a powerful shared vision that evolves through wide participation to which the key leader contributes, but which the use of authority cannot shape? And can that key leader be persuasive enough that responsibility for generating and maintaining that vision is widely accepted as a serious obligation? (pp. 78-79)

These are the two most important requirements of leaders, according to Greenleaf: The need to serve others first, and the need to lead others in working for a shared dream. Can you see how the first requirement is an inward-looking lens that shows us the responsibilities of a leader toward their group, while the second requirement is about the need for leaders to look outward to serve an inspiring dream that is larger than their group? Both lenses are needed for a healthy organization because they represent the two dynamics of life – the inner and outer *nested* relationships.

How does this help us solve the mystery of life? Let's take Greenleaf's words and put them into the same terms we used in Part 1 of this ODQTL series, (Marman, 2023a) to describe the role of relationships. When he talks about raising "people's sights close to where they have the potential to be," he is describing the *potential of a group relationship.* He is talking about the *possibilities* of working together as a group with a *shared vision* that lifts and energizes everyone.

We have seen the way *possibilities* in *relationships* have a real influence on sentient beings. Relationships draw us into meaningful lives with others, and relationships shape our choices. Greenleaf is saying that *possibilities* are also the source of the flow of life that lifts organizations and makes them healthier. This is an important clue.

We feel lifted and inspired by an organization when we work with others who share a common vision. This camaraderie is experienced only when everyone, including the leader, feels compelled by the power of the possibilities they share as a dream. The group then acts with an added sense of purpose that grows stronger than the sum of everyone's individual efforts.

We saw earlier how personal one-on-one relationships thrive on shared *possibilities*. What we are seeing now is how leadership vitalizes a team. When working with a group, the source of inspiration that has the power to lift us comes from a future goal that is larger than the group. That goal itself is a *shared possibility*. That *possibility* is a dream that can galvanize a group, such as Martin Luther King's *"I Have a Dream."*

1.3. All for One and One for All

I call this the "all-for-one" relationship. The name comes from Alexandre Dumas' famous book, *The Three Musketeers*. In his story, the musketeers fought secretly, risking their lives for king and country. As a result, they accomplished far more as a team than they could as individuals. A bond formed between them that made them stronger and healthier. Their empowerment came from their mission. Working nobly and dedicating their lives for the sake of their country changed them. They stopped acting for individual gains and adopted the motto: "All for one and one for all."

This is so significant that it needs to be added to the list of the fundamental principles for Lenses of Perception (LoP) theory. In section 3 of Part 1 (Marman, 2023a), I summarized one postulate and four principles upon which LoP theory is founded. Here is a quick review:

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. It says that everything that we see in the universe begins with consciousness. But this does not mean that the world is an illusion. Everything in the world, including all energy, matter, and spacetime are real and emerge through the following LoP Principles.

Principle One: Perception begins with the sensing of differences. This comes from the study of perception in the field of psychology. It is listed as the first principle here because it leads to all of the other principles.

Principle Two: As soon as we become conscious of others, we see the difference between "self" and others. This leads to second-person perception, where we see the "you" in others. All personal relationships begin this way.

Principle Three: Personal relationships are shared states that are private because they only exist between those involved. This describes the dynamics and the shared space in personal relationships. All of the subtle energy that passes back-and-forth between sentient beings in personal relationships comes from *relationship possibilities* that are invisible to outsiders who are not involved. Relationship possibilities also explain what quantum states *are*.

Principle Four: The shared, hidden reality of what is experienced by those in private relationships leads to third-person perceptions because we are outsiders to the relationships of others. This is what creates our shared experiences of the "world out there," which is the objective reality that traditional science has been studying for centuries.

The above principles lead to an intuitive understanding of quantum formalism (see Addendum in Marman, 2023a), that refers to the mathematical "algorithms" upon which the science of quantum mechanics is founded. However, in order to explain life, we need to add another principle:

Principle Five: The nested properties of life come from sentient beings forming all-for-one-and-one-for-all relationships. Personal bonds are created when groups of sentient beings come together for a purpose that is larger than themselves.

The premise of this paper is that all-for-one relationships are the missing piece to understanding life. It is this relationship that we find in all the nested levels of nature.

For example, the organs in our bodies are made from groups of cells that are bound together so strongly that they act with one shared purpose, such as keeping our hearts beating to distribute fresh blood – or moving our lungs to breathe in oxygen and breathe out carbon dioxide. Look at the way our brain cells work together in highly sophisticated networks, gathering sensory data into a state that makes the brain ready to trigger purposeful action on a moment's notice.

And all the organs in our body work together this same way for the sake of our life. Their work is mostly subconscious to us, showing that they are doing the work, not us. However, we play a vital role because we unite the focus of their work. When a person dies, their organs and cells soon die as well because the person is literally the source of inspiration for their lives. Without a higher purpose, the shared potential that holds the cells and organs together falls apart.

Without king and country to fight for, the musketeers would never have felt the power or nobility in their cause. This is the same point Greenleaf makes: Institutions and companies need to recognize that their life flows from a meaningful purpose. If corporations act only for the sake of their shareholders, for profits, or to keep their businesses alive, they will not have the inspiration to lift people through the nobility of work because they lack a larger dream.

If this principle is right, it suggests that we can make families stronger and healthier by finding a dream that serves a higher purpose. Hundreds of years ago, most families worked together on farms producing food for their communities. Those families acted as organs that keep towns alive. Children grew up working for a larger cause from a young age. This is something that is missing in many families today. If this theory is right, we can form stronger families if we make sure they have a vision that inspires everyone in the family to work together for something larger.

This explains why we see nested levels in biology: because each level increases its flow of life by working for a larger purpose. Groups of molecules cannot create life from chemical reactions alone. They need to work for a living cell. This means that life does not belong to any one group or individual. Life is about a relationship that emerges when groups of individuals are inspired to work for a potential that is larger than themselves. Therefore, strong communities create stronger families. And companies become healthier when everyone is working for a meaningful purpose.

If this theory is right, then one way of increasing our health as human beings is to dedicate our lives to meaningful work with others. This not only lifts our spirits; it also empowers our organs and our brain. In fact, if this conjecture is right, then, by working for a higher cause, we should see an increased flow of life all the way down to the enzymes in our cells. We can test this.

All-for-one relationships explain the startling way that slime-mold cells, with no brains, come together to act for the good of the group, even to the point of sacrificing their lives. Slime molds are compelled by a larger need, such as when food is scarce, or for reproduction, when they form a group body and act as if they are one organism. They set aside their personal needs to work for a relationship that makes them a part of something larger than themselves.

The traditional way of explaining how slime molds developed this ability is to make the vague assertion that it evolved through natural selection. This ignores the fact that working together requires choices and commitments by organisms. Even if natural selection *does* give them genetic and functional advantages to work as a group body, this does not explain why they willingly choose to sacrifice their lives for the sake of a shared purpose. Our new way of looking at this says that the added energy that comes through all-for-one relationships empowers them. That comes first, and this is what transforms evolution into a *progressive* force. This can also be tested.

Can all-for-one relationships truly be the force behind evolution and all of life? Using this as a lens, it is easy to see examples of this working at the human level: Thirteen independent colonies joined together with a shared vision to form a republic where everyone could have a say. This experiment created a huge feeling of excitement in the United States for many generations, and it spread across the planet. (Most countries have similar origin stories.) A hundred years later, the Industrial Revolution created another dream that inspired inventors and workers around the world.

This lens also shows how all-for-one relationships can increase the vitality and flow of life in our families, companies, institutions, and countries. And it shows that this relationship displays a complexity that is irreducible because it springs from the personal bonds that form between living beings working for the sake of future possibilities.

Is this why the mystery of life is so hard to see? As soon as we take cells or organisms apart to study them, we miss the invisible exchanges between them. If life springs from the inspiration that comes from working together for a meaningful dream, how can we ever see the life-force flowing after taking cells apart to study the molecules? We will never see the team spirit that drives proteins because it springs from a group relationship. If this is right, it offers an insight into this baffling complexity at the heart of life. And it shows us that this form of complexity is *far simpler* than we thought.

But using this lens also raises lots of questions: Will this new theory of life hold up after we dig into all the details? Is there convincing evidence that it works as a universal principle? Does it actually behave like a force? What happens when we shift our focus from living creatures to fundamental particles? Can we find this same behavior at the level of quanta?

The answer to all these questions is *yes*.

More importantly, this opens doors to a *quantum theory of life.* Not only does it offer a lens that shows us how life works, it also suggests where we can look to understand the mysteries of life: We need to study quantum states because they are personal relationship *possibilities* between sentient agents, especially when they work together in all-for-one relationships.

Niels Bohr, Erwin Schrödinger, and Werner Heisenberg all said that *new* science is needed to solve the hard problem of biology. I hope to show that it is possible to expand the science of quantum biology beyond the realms of physics and chemistry. It is founded on the principles of quantum states and how they behave, which physicists know well at the level of atoms, but it says that these same behaviors are also present in the lives of organisms. This is a major departure from traditional quantum theory. Therefore, significant levels of validation are needed.

Let the tests begin. It is now time for rigorous analysis. And what we learn from these tests will give us an idea of how far and deep this new science might take us into explaining how life works.

2. The Truth about Top-Down Control

There is something about our new quantum theory of life that feels strange and disturbing. If we are not conscious of how troubling this feels, it is easy to react and reject the idea outright. This is why it is worth taking a moment to look at *how* this theory is different.

For centuries, scientists have used reduction – where we break things down to analyze them, to study and understand how nature functions. This process taught us how to harness electricity and create the mechanical and electrical inventions that have changed our world.

Think about how empowering it has been for human beings to wield such a tool. It was like stealing the power of lightning from the gods. The growth of science has been propelled by the promise to gain more and more control of nature by harnessing its mysteries.

However, leadership theory suggests that the flow of life depends on a group relationship that cannot be taken apart to see how it works. More importantly, if all-for-one relationships are, indeed, the key ingredient of life that we have been missing, then we may never be able to control the life force. It may be impossible. In fact, if we want to increase the flow of life, we need to make self-sacrifices for a greater possibility. That seems like the opposite of control. This is why Robert Greenleaf (1998) asks:

> Can the key leader accept that optimal performance rests…on the existence of a powerful shared vision that evolves through wide participation to which the key leader contributes, but which the use of authority cannot shape? (p. 79)

Authority cannot control the life that flows from all-for-one relationships. In other words, there is no way to force our institutions or families to adopt a shared vision because it must emerge from the people who are working together. This means the flow of life originates from inside a country, a company, or an organism, in a way that lifts, inspires, and brings a sense of freedom that expands upward and outward to something larger. This is how nature works. Authority, on the other hand, uses reduction as a means of gaining control, like the way we control machines.

If this is right, whenever people in positions of power try to control or manipulate people, they *undermine* the flow of life. What they are doing, whether they realize it or not, is using a third-person lens, which makes them outsiders. Then they view the group as an object that can be manipulated, rather than seeing themselves as servant-first. This is why any attempt to *control* the flow of life in communities and companies weakens the all-for-one relationships that inspire people because, as soon as you try to *force* a shared vision, it disempowers everyone. This happens, for example, whenever people in positions of authority try to compel employees to work for management's goals. Whereas, acts of service and leadership do the opposite: they inspire people to join in and work with others for a greater dream.

This approach is so radically different from the traditional approach of science that it takes time getting used to. Yet, it holds great promise. If it can help us understand the mystery of life, it might solve major challenges in our modern world, especially when so many people feel disconnected from their communities and from nature. However, it also completely alters the idea of power and where it comes from in organizations. And it suggests that the flow of life, indeed, acts as a real influence that is like no other force, because it cannot be controlled from the outside.

Before accepting something this radical, we need substantial evidence to confirm that it is right. And to do that we need a much clearer model that explains exactly how life works.

Each of the nine sections in the rest of this paper, starting with this section, tests the theory in a different way. The good news is that going through this process of digging deeper into the model presented here should reveal the foundations of a fleshed-out theory of life.

I will begin, with this chapter, by studying one of the most mysterious properties of life that we need to explain. Walker and Davies say that the emergence of "top-down causation" and "top-down information flow" is so important that its appearance may define the origin of life:

> Although there is an extensive literature on top-down causation, particularly in biology, it has not been explicitly applied to the origin of life as such. The framework presented in this paper provides a well-defined definition for the transition to life, drawing on the top-down concept within an informational framework. (Walker and Davies, 2013, section 5)

While top-down causation appears to be a crucial requirement of life, Walker and Davies (2016) later admitted that they could not explain how it works: "The challenge is that we do not have a physical theory for information that might explain how information could 'call the shots.'" (p. 9)

However, the problem with all of this is that, if what I just said, above, is true, there is no way to control the flow of life. Does this mean that top-down control of life is impossible, according to our new theory of life? Yes, it does. The principle of all-for-one relationships says that it is impossible to *control* the flow of inspiration and life, if what we mean by control is the ability to fully command all-for-one relationships like the way we control machines. That simply is not possible.

Walker and Davies (2013), however, do not use the term *control*. They say *causation*. In fact, they make it clear that top-down *influence* is the best description for this causal relationship:

> Although it has been notoriously difficult to pin down precisely what is it that makes life so distinctive and remarkable, there is general agreement that its informational aspect is one key property, perhaps the key property. The unique informational narrative of living systems suggests that life may be characterized by context-dependent causal influences, and, in particular, that top-down (or downward) causation – where higher levels influence and constrain the dynamics of lower levels in organizational hierarchies – may be a major contributor to the hierarchal structure of living systems. (p. 1)

Consider the "context-dependent" information that comes with the feeling of hunger or the need to escape danger. These needs are perceived by organisms; yet, somehow, they influence their cells and organs, which make up their bodies, to move and act in the ways needed to stay alive. This is how all-for-one relationships work. This also describes inspirational leadership perfectly. A true leader plays a significant role in *influencing* a group to pursue a powerful goal that inspires them all.

Walker and Davies say that influence is not all that is needed. We also need a top-down flow of information. And this, too, is what leadership gives us. For example, the context of a situation perceived by an organism is information that flows to its cells and organs. A good leader carries a vision that inspires the group. The leader guides the group to a larger purpose by raising the group's sights and lifting their spirits to possibilities. This does not happen by force. That is what makes top-down influence so hard to detect. An organism is involved with the cells that form its body, and those cells are drawn to act together as one group for the sake of keeping the organism alive. It is this complex confluence of molecular actions that makes life possible for the animal itself.

This theory about what is happening in organisms can be tested. It says that we cannot actually *control* our body, even if we think we can. The mind-body relationship is not about control but *influence*. This means that, if our new theory of life is right, we should only be able to *lead* the cells of our body. We cannot actually control our body the way we control a machine.

It only takes a little bit of introspection to prove that this is true. For example, we have no way of directing our individual muscles to stand up and walk. Even if we know exactly which muscles to move, and in what order, we still have no buttons to push that can force those cells to act.

Horse whisperers learn the same lesson: beating horses in order to force and control them fails. Trying to *control* a horse makes the possibility of a fluid, mutually respectful relationship far less likely. Instead, horse whisperers awaken the noble nature of horses to a higher purpose by working so closely with them that both the rider and the horse act as one, in a display of artistic beauty. The horse responds to the slightest nudge of the rider, as they move like well-trained dance partners. (Marman, 2016, pp. 289-291)

Professional athletes trust their bodies to do what they want. They develop a relationship with their body that is so close that their muscles and organs follow their thoughts without hesitation. It feels so extraordinary; they call this being in "the flow," or in "the zone." That *is* the flow of life.

Babies learn how to stand and walk through trial and error. Over and over again, they try to balance on their feet, with the help of countless muscles that are needed to adapt and adjust to the slightest tilt, to keep their body upright. All of this happens without thought, but each baby must still make the effort to learn. A toddler develops this new ability through trial and error. Without knowing what it is doing, the baby learns subconsciously how to influence the teams of muscles needed to keep its balance. This is how it learns to lead its muscles in order to walk.

Muscle cells do all the work, not the baby. The baby, however, needs to discover how it feels to stay balanced and to walk, by leading. The baby must be involved in the process. This is similar to musicians in an orchestra who learn to play together through practice. Conductors act as leaders: They do not play a single note, but they guide the flow of the music played by musicians and choose which notes to accentuate. This is how the spirit of a symphony becomes *embodied*.

This describes the form of top-down causation and information flow that Walker and Davies are talking about. What does this tell us? That it is not DNA or proteins that guide the chemistry inside a living cell. The spark behind the flow of life begins with a sentient agent that enlivens a cell, leading a wild mixture of molecules into a larger life. It is the agent that pulls those molecules together. Their work is aligned with the agent. When the agent experiences hunger, the whole team feels that same need, the same way we feel the needs of our children and friends. When danger approaches, the agent leads them to safety. Proteins and enzymes do all the actual work, but they are dead in the water without the coordinating leadership of a sentient agent.

Machines do not work this way. Every mechanical reaction is driven by an external force. We *can* control them – but *not* through top-down forces. They are more like dominoes creating a chain reaction. One gear turns the next. The spark plug ignites, gas explodes, and this pushes the cylinder that drives the crankshaft.

The same thing is true in computers. Software is not controlling hardware from a higher level. Code is processed through transistors that create reactions that trigger hardware switches. (Ellis and Drossel, 2019, pp. 25-26) The only top-down control that we see with software is when people use software as a tool, just like a person who uses a steering wheel to control a car. This is when it becomes a top-down causal chain of actions because, when we use a computer as a tool, it acts as an extension of our body.

Although this gives us a graphic way of visualizing how all-for-one relationships create top-down (or "inside-out") *influences* at the human level, this falls far short of satisfying. We need concrete evidence that our new theory of life is on the right track. And we need far more technical rigor to develop a richly detailed model for how all-for-one relationships work. Let's get a better sense for what is needed.

2.1. Finding a Model for Downward Causation

"The Physics of Downward Causation" is an article by Paul Davies (2006b) that describes, in detail, the significant challenges for theories of top-down influences:

> By tradition, physics is a strongly reductionist science. Treating physical systems as made up of components, and studying those components in detail, has produced huge strides in understanding.... The behavior of gases, for example, would lack a satisfactory explanation without taking into account their underlying molecular basis. If no reference were made to atoms, chemistry would amount to little more than a complicated set of ad hoc rules, while radioactivity would remain a complete mystery.
>
> Whilst the foregoing is not contentious, differences arise, concerning whether the reductionist account of nature is merely a fruitful methodology, or whether it is the whole story. (p. 35)
>
> All physicists concede that at each level of complexity new physical qualities, and laws that govern them, emerge. These qualities and laws are either absent at the level below, or are simply meaningless at that level. Thus the concept of wetness makes sense for a droplet of water, but not for a single molecule of H_2O. The entrainment of a collection of harmonic oscillators such as in an electrical network makes no sense for a single oscillator. The Pauli exclusion principle severely restricts the behavior of a collection of electrons, but not of a single electron. Ohm's law finds no application to just one atom. Such examples are legion. (p. 36)

In other words, new properties emerge from the interactions between molecules and particles. These new properties only exist because of the dynamic nature of their relationships. Although these represent new properties that appear at a system level, as Davies points out, these new group behaviors can still be accounted for by their individual properties. For example, quantum physics explains the fluidity and wetness of water by the way water molecules attract each other loosely at room temperature. As a result, Davies says that all of these cases should be considered cases of only "*weak* emergence."

> So we are confronted with the key question: is it ever the case that an emergent phenomenon cannot be given a satisfactory reductive account, even in principle? Systems for which more is needed, not just as a convenience, but as a necessity, are called strongly emergent. Do there exist any strongly emergent systems? If the answer is yes, then we come to the next key question: in what way, precisely, does the value-added emergent 'law' or 'behavior' affect the system? A survey of the literature shows lots of flabby, vague, qualitative statements about higher-level descriptions and influence springing into play at thresholds of complexity, without one ever being told specifically how these emergent laws affect the individual particle 'on the ground' – the humble foot soldier of physics – in a manner that involves a fundamentally new force or law. (p. 38)

This is exactly what we need to show about all-for-one bonds: how these relationships affect the behavior of individual particles so that, as a group, they are able to do more, or do it better, than individual efforts can accomplish. Davies explores these questions further, in depth.

For example, he examines "self-ordering" processes, such as the funnels of wind created by tornadoes or the way boiling water can form regions where hot water rises then falls as it cools in a circular pattern of convection currents called Bénard cells. These are clear patterns of actions that emerge only on a larger scale. Davies (2006b) says that we cannot predict these behaviors *fully* from a lower level alone, because we must include the global dynamics taking place in the fluid or atmosphere where these patterns emerge. However, no new forces or laws are required to explain these behaviors.

> The fact that we need to make reference to the global circumstances to give a satisfactory account of the local circumstances is an important feature of many physical systems. It is instructive to recast this feature in the language of causation. We can ask, what caused a given water molecule to follow such-and-such a path within a given convection cell? The short answer is: the inter-molecular forces from near neighbors. But we must appeal to the global pattern of flow to provide a complete answer, because those near neighbors are also caught up in the overall convection. However, and this is the central point, we do not need to discuss two sorts of forces – near-neighbor and global forces – even though we do need to invoke two aspects in the causation story. The molecule's motion is caused by the push and pull of neighbors, in the context of their own global, systematic motion. Thus a full account of causation demands appeal to (i) local forces, and (ii) contextual information about the global circumstances.
>
> Some emergent phenomena are so striking that it is tempting to explain them by encapsulating (ii) as a separate causal category. The term 'downward causation' has been used in this context. The question then arises whether this is just another descriptive convenience…or whether downward causation ever involves new sorts of forces or influences.... In the cases cited above, the answer is surely no, but what about more dramatic examples, such as the mind-body interaction? Could we ever explain in all cases how brain cells fire without taking into account the mental state of the subject? If minds make a difference in the physical world (as they surely do), then does this demand additional, genuinely new, causes (forces?) operating at the neuronal level, or will all such 'mental causation' eventually be explained, as in the case of vortex motion…?
>
> For the physicist, the only causes that matter are, to paraphrase Thomas Jefferson, the ones that kick. Wishy-washy talk of global cooperation is no substitute for observing a real, honest-to-goodness force that moves matter at a specific place. And if the movement is due to just the good old forces we already know about, simply re-packaged for convenience of discussion, the response is likely to be a monumental 'so what?' For emergence to become more than just a way of organizing the subject matter of physics, there has to be a clear-cut example of a new type of force, or at any rate a new causative relation, and not just the same old forces at work in novel ways....
>
> When it is put this bluntly, I doubt if many physicists would hold their hands on their hearts and say they believed that any such forces exist. The history of science is littered with failed forces or causative agencies (the ether, the élan vital, psi forces…) that try to explain some form of emergent behavior on the cheap. In what follows I shall try to sharpen the idea of downward causation and ask just what it would take for a hard-headed physicist to be convinced that emergence demands any new causes, forces, or principles beyond the routine (though possibly technically difficult) consideration of the global situation. (pp. 38-39)

Davies has done a great service in adding such clarity to this subject. He spells out the problem succinctly and shows how difficult the challenge is to offer a true theory of downward causation. When he says that the only forces that matter are the ones that kick, he raises the same kind of problem that biologists face with natural selection, as I pointed out in the Introduction of Part 1 Marman, 2023a), because natural selection doesn't act in present time or at a point in space; it only acts across populations and over generations. If natural selection is to be considered a mechanism or a force, it needs to accelerate or move objects or in some way modify behavior at the same time the force is acting. This is true for all classical forces. They must also act *locally in space*.

> When discussing the interaction between spatially separated particles, we have the concept of action at a distance, which has a non-local ring to it. The sun exerts a gravitational pull on the Earth across 150 million kilometers of space. The phenomenon may be recast in terms of local forces, however, by the existence of a gravitation field created by the sun. It is the action of this field on the Earth, at the point in space that the Earth happens to occupy, which creates the force that accelerates the Earth along its curved path. There is a long history of attempts to eliminate the field concept and replace it with direct non-local inter-particle action (e.g. the Wheeler-Feynman theory of electrodynamics), but these theories run into problems with physical effects propagating backward in time and other oddities. Overwhelmingly, physicists prefer local field theories of causation.
>
> This fundamental locality is softened somewhat when quantum mechanics is taken into account. For example, two electrons may interact and move a large distance apart. Theory suggests, and experiment confirms, that subtle correlations exist in their behavior. However, it has been determined to most physicists' satisfaction that the existence of such non-local correlations does not imply a causative link between the separated particles. (A lot of popular articles convey the misconception that separated quantum particles in an entangled state can communicate information faster than light. These claims stem from confusion between correlation and communication.) (p. 40)

Davies is right that quantum entanglement does not act as a force; it is a correlation that exists when particles share the same quantum state. Being entangled causes the particles to stay aligned with each other. This means that one particle does "constrain" the state of its entangled partner. However, this shared state cannot be used to send messages from one particle to the other faster than the speed of light, and it does not act as a force.

But this raises the question: How *do* entangled particles stay aligned when they are far apart? As we saw in Part 1 of this ODQTL series (Marman, 2023a, p. 64), Ruth Kastner's Relativistic Transactional Interpretation of Quantum Mechanics (RTI) (Kastner, 2013) offers an explanation: These shared quantum states exist outside of spacetime. LoP Interpretation agrees with this and adds that quantum states exist outside of spacetime because they are shared relationship possibilities that cannot be seen by outsiders. Shared relationship states exist only between the particles that are entangled. We experience the same thing when we form private relationships with others.

If you want to better understand what entanglement means, it helps to know the way physicists create a pair of entangled electrons or photons. They do it by ejecting two electrons or two photons from the same atom at the same time. In other words, particles become entangled after living and working together in an atom. The same thing happens with people; we get entangled when we live and work together as well.

But the real question that Davies is asking here is this: *Do non-local forces actually exist?* As we saw in Part 1 of this ODQTL series, p. 67, RTI shows us that the answer is *yes*, there are non-local forces, but only when those forces carry no energy. As soon as real energy is involved, the energy must be carried by real particles, such as photons that travel through spacetime from emitters to absorbers. However, before a wave function collapses, an exchange of virtual photons *do* create a non-local force of attraction or repulsion that has a real *influence* on charged particles.

This is how the force of repulsion between electrons emerges on the quantum level. And the interesting fact about these invisible exchanges is that there is no way to determine which of the two electrons emits a virtual photon and which absorbs it (Kastner, 2015, ch. 4). In other words, there is a *mutual* exchange between them with no directionality. This exchange creates the static force of *repulsion*. Static electrical *attraction* works the same way, except the virtual photons are in-phase, rather than out-of-phase, with the particles (Kastner, 2017, p. 10). Neither static attraction nor static repulsion have "kinetic" energy. They are forces with only "potential" energy.

And because repulsion and attraction emerge *between* particles, this means that these forces are not localized to one particle or the other because both particles are involved. Relativistic quantum theory suggests that all forces emerge this way. In other words, at the quantum level, we do not see forces acting the way Newton says they should. Forces are supposed to *drive effects*. Instead, forces at the quantum level emerge *between* charged particles. Therefore, forces *are effects*, they are end results, not true causes. Forces emerge between charged particles through dynamic one-on-one relationships in the same way that attraction and repulsion emerge between people.

When Davies says that physicists *overwhelmingly* prefer local theories of causation, there is a good reason for this: When it comes to forces that carry energy, there are always local fields involved. This is true, and we see this when a real photon is needed to carry energy from an emitter to an absorber. The real photon must travel through spacetime and through the electromagnetic (EM) field to deliver its packet of energy. This is the traditional way physicists look at EM fields, but it leaves out an important part of the quantum story. This is worth a closer look.

When Wheeler and Feynman (1945) created their absorber theory, they showed that a non-local quantum exchange, acting as "direct action," can explain everything that happens between the emitter and the absorber. However, their theory was still a classical theory because it treats these exchanges as if they are causal waves traveling through spacetime. In other words, these exchanges act as waves carrying energy. As I explained in Part 1, p. 65, Wheeler and Feynman discovered that all the waves carrying energy cancel out except for the waves directly between the emitter and the absorber. So, in fact, they did succeed in eliminating the need for a local field.

However, when they tried to apply their theory to the quantum level, they found that, in some cases, emitters and absorbers interact with their own field, which is called "self-action." They could not get rid of self-action because it produces a very real effect called the "Lamb shift," named after the physicist who discovered it. The original goal of Wheeler and Feynman's "direct action" theory was to eliminate this self-action because they thought it would result in infinite energies. After seeing that they could not eliminate self-action, they abandoned going any further with their quantum analysis. They should not have given up so quickly.

Years later, Davies picked up the ball and finished the quantum analysis. In the process he showed that the direct-action theory works, and it is fully equivalent to the standard quantized field theory. He also showed that both an absorber and an emitter wave are needed to create a real photon. However, by that time, both Wheeler and Feynman had lost interest. This shows us that Davies is speaking from personal experience when he says (2006b) above,

> There is a long history of attempts to eliminate the field concept and replace it with direct non-local inter-particle action…but these theories run into problems with physical effects propagating backward in time and other oddities. Overwhelmingly, physicists prefer local field theories of causation. (p. 40)

Physicists might prefer the idea of local field theories, but direct-action theory is perfectly valid. Davies proved that it is equivalent to standard-field theory. More importantly, it opens the door to a new way of interpreting what is really happening. That is why this is so important.

Kastner discovered that, in fact, there is no problem with "self-action" because the quantum exchange that worried Wheeler and Feynman only creates a force that carries no energy (Kastner, 2020, p. 10). Further, there is no single place in spacetime to assign these quantum interactions because they are non-local, showing that these interactions take place outside of spacetime. (p. 2) This eliminates the concern that absorber-wave functions are traveling backwards in time. They are not because they exist outside of spacetime. This makes intuitive sense because future relationship possibilities *do* influence our choices. We call this *anticipation*. The future *does* have a clear influence on our relationships when we weigh future possibilities before making a choice.

Even Wheeler has shown interest in reviving his theory. He had a change of heart and said that it offers a correct and valid description of radiated energy. In fact, he proposes it as a possible pathway to solving the quantum-gravity problem. Wesley and Wheeler (2003) wrote:

> [Wheeler-Feynman theory] swept the electromagnetic field from between the charged particles and replaced it with "half-retarded, half advanced direct interaction" between particle and particle. It was the high point of this work to show that the standard and well-tested force of reaction of radiation on an accelerated charge is accounted for as the sum of the direct actions on that charge by all the charges of any distant complete absorber. Such a formulation enforces global physical laws, and results in a quantitatively correct description of radiative phenomena, without assigning stress-energy to the electromagnetic field. (p. 427)

The point of all this is that non-local forces do exist, but only when they carry no energy. And exchanges of energy can be treated as direct-action events. This is a valid model. It is not necessary to invoke fields as the cause because fields are just the result of all the relationship possibilities. Therefore, we can treat transactions of energy as events that start with invisible exchanges between charged particles, leading to a joint agreement to act. This is a perfectly valid way of interpreting what is happening.

This is important because LoP Interpretation says that, since quanta behave this way, then the same behavior should also exist between organisms that have receptive and responsive relationships with each other. In other words, real forces should emerge between life forms in a way that causes them to attract or repel each other, which, of course, is exactly what we experience with others. And, when we feel that special "chemistry" with another person, it *does* feel like attraction, and it certainly does affect the choices we make. This story fits because we *are* quantum systems.

However, none of these feelings of attraction and repulsion between people are top-down forces. They work the same way as the weak bonds of attraction between water molecules created by electrical charges. There is no top-down causation with the electromagnetic force.

But, when a group bond forms and inspires the team to pull together with an all-for-one spirit behind a leader, this is different. It is different for two reasons: First, because the whole group shares this state together, which tells us that they are entangled. Second, because leaders have a real influence over the group. This brings us to exactly how Davies defines top-down causation:

> The problem of downward causation from the physicist's point of view is: How can wholes act causatively on parts if all interactions are local? Indeed, from the viewpoint of a local theory, what is a 'whole' anyway other than the sum of the parts?
>
> Let me distinguish between two types of downward causation. The first is whole-part causation, in which the behavior of a part can be understood only by reference to the whole. The second, I call level-entanglement (no connection intended with quantum entanglement, a very different phenomenon), which has to do with higher conceptual levels having causal efficacy over lower conceptual levels. (Davies, 2006b, p. 40)

Davies made a serious effort to find any possible examples for "whole-part causation," but he failed to find any that were compelling. All attempts at treating *wholeness* as a force fell short. So, he then turns to cases of what he calls "level-entanglement":

> In common discourse we often refer to higher levels exercising causal efficacy over lower. Think, for example of mind-brain interaction: 'I felt like moving my arm, so I did.' Here the mental realm of feelings and volitions is expressed as exercising causal efficacy over flesh. Another example is hardware versus software in computing. Consider the statement: 'The program is designed to find the smallest prime number greater than one trillion and print out the answer.' In this case, the higher-level concept 'program' appears to call the shots over what an electronic gizmo and printer and paper do. Many examples may be found in the realm of human affairs, such as economics. Pronouncements such as 'stock market volatility made investors nervous' conveys the impression that the higher-level entity 'the stock market' in part determines how individual agents behave.
>
> In the latter two examples at least, no physicist would claim that there are any mysterious new physical forces acting 'down' from the software onto the electronic circuitry, or from the stock market onto investors. Software talk and reference to 'market forces' in economics do not imply the deployment of additional physical forces at the component level. The existing inventory of physical forces suffices to account for the detailed behavior of the components. Once again, the best way to think about downward causation in these examples is that the global system harnesses existing local forces.
>
> The mind-brain example is much harder because of the complexity and openness of the system. A more dramatic example of mind-brain causation comes from the field of neurophysiology. Recent work by Max Bennett in Australia has determined that neurons continually put out little tendrils that can link up with others and effectively rewire the brain on a time scale of twenty minutes! This seems to serve the function of adapting the neuro-circuitry to operate more effectively in the light of various mental experiences (e.g.

> learning to play a video game). To the physicist this looks deeply puzzling. How can a higher-level phenomenon like ‘experience’, which is also a global concept, have causal control over microscopic regions at the sub-neuronal level? The tendrils will be pushed and pulled by local forces (presumably good old electromagnetic ones). So how does the force at a point in space (the end of a tendril) ‘know about’, say, the thrill of a game? (p. 42-43)

The mind-body problem is not easy to solve with classical forces. This is what makes this such a hard problem for biology. However, Davies is making another important point here: When it comes to mind-body influences, we do not see *new forces* acting at the local level. The tendrils are pushed and pulled, just like our muscles, by traditional local forces. If top-down causation is happening, a higher level must be *harnessing* local forces somehow. This is why he calls this “level-entanglement,” because the local level aligns itself to the needs of a higher level. There is no visible “kick” from the higher level, only an alignment that is similar to entanglement, and this is what makes top-down causation so difficult to explain and verify.

The good news is that this fits exactly with the LoP description of all-for-one relationships. Remember, leaders rally people together, but it is the employees who do the actual work. Leaders carry the vision that invigorates and inspires the teams. True leaders do not force their teams. Teams follow a leader to achieve more meaningful goals than they can achieve on their own. As a result, their work becomes more than the sum of their parts because each group is able to do more, or do it better, when they work in synchrony together. Plus, they feel lifted and empowered by working for a larger cause, creating an increase in vitality and health for everyone involved.

Davies (2006b) concludes his article with these remarks:

> As I have already stressed, top-down talk refers not to vitalistic augmentation of known forces, but rather to the system harnessing existing forces for its own ends. The problem is to understand how this harnessing happens, not at the level of individual intermolecular interactions, but overall – as a coherent project. (p. 48)

I started with leadership because it shows how all-for-one relationships work from a perspective we can relate to as human beings. This gives us a lens that shows how organisms are able to harness the cells and organs of their bodies. It makes sense that cells and organs do *all* the real work to preserve the flow of life for animals and plants, dedicating themselves to the organism they belong to because this is their life as well.

This fits with what Davies calls “strong emergence,” except that all-for-one relationships *do* produce a “vitalistic augmentation” of work when well-functioning teams inspire and empower us. They increase our feeling of energy and health. We know this from personal experience. And this is why teams accomplish more than individuals working alone. The added vitality feels like energy, but it is not. It is a force that carries no energy. I think it is fair to call this “the life force.”

Of course, physicists need far more detail. They want to know how this works for the “foot soldiers” on the ground, as Davies put it, which means showing how all-for-one relationships move fundamental particles, atoms, and molecules. The next few sections offer a coherent theory, based on quantum principles, for how this works.

But, before we move on, Davies (2006a) offers a fascinating overview on the importance of emergence and top-down causation in the preface to the same book in which his above article was published:

> Emergence thus possesses a curious status. It has a long history within philosophy, but its position within science is both recent and tentative. For emergence to be accepted as more than a methodological convenience – that is, for emergence to make a difference in our understanding of how the world works – something has to give within existing theory. There is a growing band of scientists who are pushing at the straightjacket of orthodox causation to 'make room' for strong emergence, and although physics remains deeply reductionistic, there is a sense that the subject is poised for a dramatic paradigm shift in this regard. And where physics leads, chemistry and biology are likely to follow.
>
> Why would this shift be important? If emergence (in the strong sense) were established as a bona fide part of physics, it would transform the status of the subjects within the hierarchy that physics supports.... Emergence in biology would open the way to biological laws that supplement the laws of physics, perhaps enabling scientists to pin down exactly what it is that distinguishes living matter from nonliving matter. The greatest impact would surely be in the field of consciousness studies, where the mind-body problem could be solved by appealing to mental causation as a legitimate category augmenting, but not reducible to, physical causation. This would enable scientists to take consciousness seriously as a fundamental property of the universe, and not as an irrelevant and incidental epiphenomenon.
>
> Strong emergence would have a profound effect in ethics, philosophy, and theology too. Take, for example, ethics. In a reductionist world view, all that really matters are the base level entities and their laws, for example, subatomic particles and superstrings. Life, mind, society, and ethics are all regarded by reductionists as highly derivative special states of matter with no claim to represent basic aspects of reality. Those who argue that there is a moral dimension to the universe, that is, that there exist genuine ethical laws that may stand alongside the laws of physics in a complete description of reality, are dismissed by reductionists with the 'no-room-at-the-bottom' argument: how can there exist distinct ethical laws when the laws of physics already account for everything? But if mental, social, and ethical laws emerge at each relevant level of complexity, in a manner that augments but does not conflict with the laws of physics, there is room for the existence of ethical laws. Categories such as 'right' and 'wrong' could possess an absolute (law-like) rather than a socially relative status.
>
> If emergence is eventually embraced by science, it raises an interesting theological issue. The founders of physics, such as Galileo, Kepler, and Newton, were all religious, and they believed that in doing science they were uncovering God's handiwork, arcanely encoded in mathematical laws. In this world view, God sits at the base of the physical reality, underpinning the mathematical and rational laws of physics, constituting what Tillich calls 'the ground of being'. Religious emergentists might be tempted to locate God at the top of the hierarchy, as the supreme emergent quality. There is thus apparently a tension between reductionism and emergence in theology as well as in science. (p. xii-xiii)

This shows how much is at stake, if all-for-one relationships can offer a scientific explanation for strong emergence and top-down causation. As Davies says, it would revolutionize many fields if we could show that top-down causation exists everywhere, from the simplest forms of matter all the way to the most complex expressions of life.

What the first article above by Davies reveals is that two different properties are involved with top-down causation: First, we see entanglement between a larger level and a smaller nested level, so that the larger-level *influences and constrains* the smaller level. Second, at the same time we see agents at the smaller level coming together to do *all* the work as a team, as if an influence pulls them together to act for the sake of the larger level. This just happens to be exactly the way all-for-one relationships work.

This offers an explanation for why cells work together so closely and how the cooperation of families and communities can be inspired by a higher cause. However, we have a long way to go to satisfy physicists. They need to see how this works as a real force influencing particles.

3. The Strong Force *Is* an All-for-One Relationship

According to our new theory, life acts as an influence that vitalizes and brings health to organisms, like the old idea known as "vitalism" that was laid to rest long ago. Vitalism was buried for two main reasons:

- First, because physicists found no evidence that there are any more than the four known forces of physics. Every physical interaction between particles can be explained by these four forces.
- Second, because no one could explain how vitalism works scientifically. All the explanations proposed sounded more like magic, religion, or myth than science.

Our new theory says that invisible influences emerge between sentient agents in relationships, creating attraction and repulsion. And the good news is that this theory can be tested because it offers a clear description of how the life force should work. This is where things get interesting.

In Part 1 (Marman, 2023a, p. 38) we saw how particles attract and repel each other. Physicists agree that these forces emerge at the quantum level through dynamic *invisible exchanges between them*. If all-for-one relationships are the key to life, and if quantum particles are sentient agents, then we should see this same group bond working at the level of quanta. We should be able to find cases *where quanta combine to form dynamic teams*. This is a major hurdle for our theory of life.

It turns out that the "strong force," one of the four fundamental forces of physics, fits the pattern we are looking for in surprising detail. It is stunning to see how closely the strong force matches the behavior that we find in all-for-one relationships. Let's take a look.

In this section I will start with a simplified model for the strong force that captures the most important elements needed to compare it with what we learned about all-for-one relationships. In the next section, I will dig into the complexities of the strong force, giving us a more robust picture.

The Standard Model of Particle Physics uses quantum theory to describe mathematically how the strong force works. This field theory is called "quantum chromodynamics." The equations are highly complex, but they are also elegant in how they are derived from deep underlying principles of symmetry and "gauge theory." They are also quite accurate, which validates the model.

The Standard Model says that the strong force requires *three complex dimensions* to represent the way this force works (Schumm, 2004, pp. 267-269). The word "complex" here means that these dimensions are based on what mathematicians call "imaginary" numbers – numbers that use the square root of -1. We can also say that these dimensions are hidden. They are not a visible part of our spacetime world. In the Addendum of Part 1, we saw how complex dimensions are used in quantum formalism for quantum states and how LoP principles allow us to interpret these same complex dimensions to represent personal relationships. The same is true with the strong force.

Each dimension represents a relationship between quarks that creates attraction. According to the Standard Model, this is how the strong force works: If three quarks are labeled A, B, and C, the strong force forms relationships that create attraction in three ways: AB, BC, and AC. In other words, the strong force engages when three quarks form relationships that attract each other in a way that forms a group (Schumm, 2004, pp. 267-270).

With electromagnetism, photons are exchanged between charged particles to create attraction or repulsion. With the strong force, particles called "gluons" are exchanged to produce attraction.

Strong-force charges are different from electric charges in a number of ways. First, strong-force charges are called "color" charges. The term "color" has nothing to do with visual color – the name symbolizes a key property of the way these invisible charges create strong-force attraction.

Physicists say that each quark carries one of three possible charges: "red," "blue," or "green." The reason that red, blue, and green are chosen as labels is because combining red, blue, and green makes white. This helps picture the most essential trait of the strong force: it attracts three quarks together only when each of the three quarks carries a different color charge – in other words, one red quark, one blue quark, and one green quark. Remember, these colors cannot be seen. They are used here as metaphors. The point is that the strong force engages when all three quarks unite in a way that attracts each of the quarks equally to each other at the same time. When this happens, the group ends up being "white," which means the group has no residual color charge left over. This is important because it means the strong force acts directly only on quarks that are bound together.

There is another layer of complexity to the strong force: Not only must each of the quarks form a complementary relationship that attracts them to each of the other quarks (AB, BC, and AC), and not only do they all join together as a matched group (the way red, blue, and green combine to make white), the *gluons* that are exchanged between the quarks must also join together by creating matched bonds as well. The reason this happens, according to the Standard Model, is because gluons also carry color charges.

As a result, when the strong force is involved, all of the quarks and all of the gluons attract each other in exactly the right way. This sounds remarkably similar to what we learned about all-for-one relationships. However, one thing seems to be missing: the "one" who is the leader.

What happens when this amazing feat of magic, known as the strong force, takes place? Protons, neutrons, or other "baryon" particles are created. (Schumm, 2004, p. 269) The force that holds protons and neutrons together is so powerful that protons and neutrons act as individuals. In other words, the strong force combines all of the quarks and gluons to make *one* proton or *one* neutron. This is truly all-for-*one*. This is how quarks and gluons combine as a group to form the *bodies* of protons and neutrons. This is surprisingly similar to the way cells form the bodies of animals.

The strong force is also the force that pulls neutrons and protons together to form the nuclei of atoms. This displays the same *nested relationship* that we see in living organisms: Quarks make the bodies of protons and neutrons, and protons and neutrons join to form atoms.

The Standard Model also explains why the strong force cannot be fully controlled from the outside: Gluons influence each other. As I said in Part 1 (pp. 30-31), when forces have an influence on each other, it is no longer possible to separate them into individual forces. They act as one complex combined force that cannot be reduced. This property of complexity is exactly the same trait that biologists have long considered the key behavior of organisms. Electromagnetism does not act this way because photons carry no charges, which is why they have no direct effect on each other (Schumm, 2004, pp. 270-271).

This non-reducible property of the strong force shows up in a startling way when it pulls quarks together inside a proton: The force does not decrease with distance. All other forces get weaker as objects get farther apart, but not the strong force because gluons respond to each other in a peculiar way: As quarks spread apart, the strong force increases, much like stretching a rubber band, to keep the bond between them constant and to bind the quarks tightly together through real energy.

As you see, the mathematical relationship between gluons and quarks is complex. They produce three forces that bind the quarks with real energy, while the gluons create a static force that affects other gluons in exactly the right way to act as one combined force with the quarks. As a result, we cannot take quarks apart to see how this works because the strong force acts this way only when quarks join together as a team, just like all-for-one bonds. **No other force works this way.**

Also, this responsive behavior between quarks is not controllable from the outside. A proton or neutron can be broken apart only with a tremendous amount of energy, but when this happens, the quarks – if they survive – join together *immediately* with other quarks. The end result is that **no one has ever seen a quark on its own** (Schumm, 2004, p. 274). And when quarks are bound together, the force that binds them has virtually no influence outside their group because they end up with no net color charge. All of this *matches* the behavior of all-for-one relationships.

In fact, the similarities were such a surprise that I immediately started looking for differences. I needed to know: Are there discrepancies that invalidate this appearance that the strong force acts as *the same force* that we see in all-for-one relationships? I needed to be sure that all the core traits of all-for-one relationships agree with all the core properties of the strong force. Plus, all of the governing principles of the strong force must apply equally to the way all-for-one relationships work in organisms as well. This is a high bar.

We are not comparing mathematical formulas here. We are studying the principles that govern the Standard Model and how they compare to life forms that act as teams. This might seem strange to physicists because we are focusing on something that seems qualitative rather than quantitative. Physicists taught themselves to focus on mathematical models because they could find no way to make sense of quantum mechanics (QM). Mathematical formalism is the foundation of QM.

However, in the Addendum of Part 1, I showed that not only is the LoP Interpretation valid, but it also offers us a way to make sense of QM. The essential piece that has been missing from physics and chemistry is the role of personal relationships. According to LoP theory, relationships between sentient agents, and the role of possibilities in relationships, go to the heart of the quantum mystery.

We are now testing this interpretation further. It is showing us that that the strong force can be interpreted as the force that emerges when sentient agents work together as a team. If differences exist between this interpretation and the way quarks actually behave as a group, then all-for-one relationships cannot explain the strong force. This is why I am looking for discrepancies. Let's look at some examples of what, at first glance, look like differences.

First, the Standard Model tells us that each of the quarks must carry a different color charge. This creates a distinction between the quarks that is necessary for the force to create attraction. The strong force only engages when the charge of each quark is distinctly different. If this is true for quarks, it should also be true for human beings. At first, I could not see any way that this strange quirk of quarks related to anything we experience in human relationships. However, the realization suddenly hit me that this is describing a crucial trait of all-for-one relationships: Diversity makes teams stronger. Until that moment, I had not noticed how important this property is to all-for-one bonds between organisms.

Well-functioning teams inspire people to specialize. When everyone is the same, teams are weak. They only become effective when everyone's strengths and weaknesses are complementary. A football team needs players who excel at passing, others who are natural receivers, some who are great blockers, and those who have a talent for stopping receptions. Differences make teams better. This is why working as a group naturally pushes people to specialize. From this, we learn to appreciate our differences. Remember, as I said earlier (pp. 94-95), this is what we find in healthy families; they learn to appreciate their differences.

We see this same principle at work in the lives of slime molds: These single-celled organisms specialize for the sake of the group. Some die to kill off dangerous bacteria, acting like immune cells. Some die to create stalks for reproduction. Others create spores to give birth to new slime molds. They only take on these specialized behaviors when working as groups. (Zimmer, 2011)

When cells in an embryo multiply, they start out as genetic clones of each other. However, as soon as the third division, cells begin specializing. It is still a mystery why this happens and what guides this process. If LoP principles are correct, all-for-one relationships encourage this process of specialization because differences make the working-together bond stronger.

If these biological insights are right, this suggests that the three-way bond between quarks does not form because one quark happens to be "red," one happens to be "blue," and one is "green." No, it tells us that all three charges find a way to complement each other to assure their net color stays “white.” We will soon see that this is exactly what the Standard Model says is happening.

Second, quarks inside protons and neutrons spin together as one. Exactly why this happens is still not understood completely. This “open problem” is called the “proton spin crisis.” (Jaffe, 1995, pp. 24-30) Current theory can explain about 70-80% of the spin of a proton or neutron, leaving 20-30% unexplained. If the premise of our new quantum theory of life is correct, part of the reason that quarks spin as one unit is because they have a strong all-for-one relationship. Quarks spin as one because of the bond that holds them together. (More on this in the next section.)

The problem with this proposal is that we never see the molecules in cells spinning together or the cells in our body spinning as teams – thank goodness. This appears to be a difference. However, the biggest question about cellular life is why proteins and enzymes act to keep the energy flowing. Doing so requires a synchronized dance that is so highly coordinated that no one can explain it. This goes to the heart of the mystery in biology that we are trying to solve.

The description of the dance between quarks inside of a proton sounds like nothing more than simple spin, but it turns out to be far more complex, as I will show in the next section. There is a “sea” of quarks popping in and out of existence that join the other quarks to create the body of a proton. Molecules and enzymes in a living cell also perform highly orchestrated dances together as a single team. In biology, this is often recognized as a sign of top-down causation. Thus, what first looked like a difference now looks more like a similarity between quarks and organisms.

Third, another strange property of the strong force is that we never see gluons flying around outside of atoms. Since gluons are massless, like photons, they should fly far beyond the nucleus of atoms. Scientists should see them everywhere on their own, but they do not. This issue is called the “color containment problem” and is one of the unsolved problems in physics (List of Unsolved Problems in Physics, 2023). If gluons never travel outside of atoms, then it would be impossible for the strong force to create bonds between the cells of a body so that they work as a team. This creates be a major problem for our new theory that says all-for-one relationships are governed by the same principles as the strong force. In other words, we need to be able to explain “how these emergent laws affect the individual particle ‘on the ground’ – the humble foot soldier of physics,” as Davies said in section 2.1. If gluons are not carrying the force in all-for-one relationships, then the strong force is not involved.

However, there is an issue with the strong force that is baffling. The strong force does not pull quarks together as a group until all three quarks and three gluons bond; when they all respond to each other in such a way that the combination creates one proton or one neutron. What turns all of the one-on-one interactions between quarks and gluons into one strongly bound unit?

The Standard Model says this happens only when red, blue, and green color charges combine to create white, but this does not explain the principle that shows us *why* this amazing dance is so unified. The Standard Model only describes *what* is happening. The hard part of the problem is *why* one-on-one quark attractions (AB, BC, and AC) combine with all the gluon attractions to create forces that influence each other in just the right way to form a self-contained group. This cannot be reduced to simple one-on-one forces as we see in electromagnetism because something happens at the group level that keeps the bond unified. (We'll explore this in more detail in the next section.)

However, this mystery is not a problem with human all-for-one relationships because we know that teams are formed by people, not by external forces. Team bonds emerge between people when they work together as a group. The strong force seems to emerge between quarks in the same way.

If we take this comparison one step further, and if all-for-one relationships are the true source behind the strong force, then this suggests the strong force *should* reach beyond the nuclei of atoms. There should be nothing preventing this. However, the strong force should *only act on sentient agents involved in their group*. This explains why gluons are never detected outside of their bonds.

If this LoP Interpretation of the strong force is right, it leads to the prediction that the strong force *can* reach far beyond atoms, and I have found surprising evidence that might support this in a way that is testable. This will be the subject of a future paper in this ODQTL series.

Fourth, I said that all-for-one relationships grow stronger when they occur in nested life forms. For example, the flow of life *increases* when families are involved in a strong community. If this is a key trait of all-for-one relationships, then we should see this same trait in the subatomic world as well. It turns out that we do. It shows up in the lifetimes of neutrons. Neutrons are considered stable when inside of atoms. Occasionally they decay into protons, but this is rare. When outside of atoms, however, neutrons decay much faster. They have a half-life of about 15 minutes. (Moskowitz, 2014)

In fact, this is true for all baryons, which are particles formed by three quarks through the strong force: They all live longer inside of atoms than on their own, suggesting their bond is stronger when inside a nested relationship. Finding a similarity like this between the strong force and all-for-one bonds, between quarks and human beings, offers some surprising validation.

Fifth, if the LoP Interpretation of all-for-one relationships is right, then there should be more than just a strong attraction between quarks. There should also be an attraction they share that pulls them together as a team. For quarks, the proton or neutron itself should be the "*one*" that unifies them. If this is right, we cannot leave out of the equation this bond to the leader, the "*one*." The proton or neutron needs to act as the *one* in the "all-for-*one*" relationship. Without this relationship to the *one*, the bond should fall apart. In other words, the *reason* individual color charges combine to turn "white" is because each quark has its own personal relationship to the *one*. This creates a shared bond with the *one* that keeps the quarks aligned with each other.

This is a serious issue because LoP principles say that attraction in all-for-one bonds only emerges between *sentient agents*. They must be *personal* relationships. We cannot have a personal relationship with a mound of sand – only with other beings or a community of beings. If we look at the relationships between our cells and us, this makes sense because cells are sentient agents, and so are we. But if the strong force is the result of all-for-one relationships, then this means that each proton and neutron must also be sentient. For quarks to work together as a group, they must share a bond. And if a proton is the *one* they share a bond with, this can only form a dynamic relationship if that *one* is a sentient agent as well.

Clearly, no scientific experiments have verified anything even close to an assertion like this. However, protons and neutrons do all share a remarkable trait with fundamental particles: They act as individuals. When studying the way protons interact with other particles, we can forget about the quarks that form their bodies because each proton acts as such a cohesive individual.

And there is no way to prove that a proton or neutron is sentient because outsiders will never be able to measure this. Of course, the same is true for fundamental particles. This is exactly what makes this whole theory that particles are sentient so difficult to prove. However, if protons and neutrons *are* sentient, the first thing we should see is them acting as individuals, and we do.

The second thing is that, when it comes to relationships between sentient agents, the behavior should be unpredictable. This clearly holds true for protons and neutrons. Just look at how atoms decay: There is no way to predict exactly when decay will happen. We only know the average "half-life." And, as I said above, neutrons decay randomly as well, especially when they are outside of atoms.

While these two behaviors look promising, they are not nearly enough. This is so crucial to our new quantum theory of life that we need to find much stronger evidence that, indeed, all-for-one relationships define the way that the strong force works. Secondly, we need to confirm that the strong force acts as a true example of downward causation.

If we can find evidence that a proton acts clearly as a *one*, an individual, and that this *one* does indeed use downward causation to hold the quarks together as a unit that follows the *one*, then the claim that all-for-one relationships are the principle behind the strong force might make sense. Fortunately, this is exactly what we find when we dig deeper into the details of how the strong force works according to the Standard Model.

4. Does the Strong Force Use Top-Down Causation?

LoP Interpretation offers an explicit explanation for the strong force based on principles. These principles tell us how and why all-for-one relationships form between sentient agents. This appears to describe the way that protons and neutrons are created: Groups of quarks are pulled together when they act together as teams. Each quark needs to be distinctly different to create attraction. And we find the same qualities of nesting and complexity with a proton that we see with living cells. The explanation for how this works fits almost exactly with the Standard Model equations for the strong force, except for one detail: The Standard Model says nothing about the proton or neutron acting as an active agent in this bond.

This reveals a major problem that needs to be resolved because most physicists see the proton as being fully created by the forces of attraction between the quarks, with these forces being carried by gluons. All of the equations in the Standard Model are designed specifically to explain the strong force as nothing more than the result of properties already present with quarks. If this is true, then no new force emerges at the level of the protons and neutrons because the strong force is simply a law of nature that compels quarks to attract, just as electromagnetism compels water molecules to act as they do.

However, treating the strong force as a law of nature does not get physicists off the hook. The real question is this: Does the strong force use top-down causation? This brings us back to what Davies (2006b) says about the requirements needed to show *strong emergence*:

> So we are confronted with the key question: is it ever the case that an emergent phenomenon cannot be given a satisfactory reductive account, even in principle? Systems for which more is needed, not just as a convenience, but as a necessity, are called strongly emergent. Do there exist any strongly emergent systems? If the answer is yes, then we come to the next key question: in what way, precisely, does the value-added emergent 'law' or 'behavior' affect the system? (p. 38)

It turns out that there is something different about the strong force that we do not see with any other force: The properties of individual quarks on their own cannot fully explain how the strong force works because their behavior transforms so completely when they act as a group. The Standard Model offers a clear mathematical description of *how* this happens, but not *why*. *Why* do forces that start as one-on-one relationships between quarks change into a force with a unified group bond? Let's look closer at what the Standard Model says:

Each quark possesses a color charge, and quarks are attracted if their color charges are different. That's fine, and this is similar to the way electrical charges work in electromagnetism. This also fits perfectly with the first LoP founding principle: perception is based on differences (section 1.3). This is why stark differences create the strongest attraction. But this only describes the one-on-one forces between quarks. Why do three quarks attract each other as a team? According to the Standard Model, this force is created by an exchange of gluons, but the only way for this model to work is if the gluons are responsive to each other, to the quarks, and *to the group as a whole*. This is far more than one-on-one attraction, and it requires far more than the attraction between quarks.

Remember, gluons create forces of attraction that grow stronger in a precise way when quarks move farther apart. All other forces *get weaker* over distance, but the attractive forces between quarks actually *increase*, like an elastic band, to pull the quarks together, so the energetic bond holding them together remains constant. This is surprising behavior. Physicists had never seen anything like this before, as Bruce Schumm (2004), professor of physics at the University of California at Santa Cruz, says:

> In the 1960's…it was found that it was simply impossible to construct…a wave function that represented the known properties of the proton and neutron. Only by hypothesizing, with no other motivation than to make these wave functions work out, that quarks carry a novel property known as color…was the quark model rescued.
>
> According to the theory of color, each quark can come in one of three colors: red (R), blue (B), or green (G). No one, of course, is claiming that quarks actually come in three decorative shades; it's just that, mathematically, when an extra factor is added into the wave function to account for this possibility, the rest of the wave function suddenly makes physical sense.... (p. 267)
>
> This pattern of interrelations provides that the combination of all three color charges, in equal amounts, yields a net color charge of zero! This property is quite unusual. It's somewhat akin to combining three particles with positive electric charges and winding up with a combined object that is electrically neutral – only the three particles have equal

> positive amounts of three different kinds of strong-force charge: red, blue, and green…. This property is essential. The existence of baryons, among which we count protons and neutrons, is predicated on the fact that the three quarks that form them, when combined have no net color charge. (p. 269)

Color charges, as Schumm explains, describe the attraction between quarks. Color charges never cause repulsion, only attraction. So far so good. But how does this ability to combine three equally charged particles make one particle with no net charge? This is unique. None of the other forces act this way. Exactly what needs to happen in the wave function for this to happen?

First, there needs to be a way to correct for quarks that change colors. Schumm puts it this way: "the group of transformations that rotate the three quark colors into one another must be the group of complex three-dimensional rotations: one complex dimension for each quark color." (p. 268)

What Schumm is saying here is that quarks rotate through "color space." This means that quarks transition from blue to other phases in color space, such as "half-green/half-red." Unfortunately, these transformations mess up the relationships between the quarks. (p. 270) Physicists need to add something else to the story to make this work: Gluons must also carry color charges (p. 271) because it is the job of gluons to "restore the delicate balance." (p. 270) The gluons must keep all of the color phases aligned as the quarks rotate through color space so the net color charge of the proton remains zero. This is how the differences in the charges between the quarks are made to complement their work together with each other. This is exactly what makes a well-functioning team.

This technical description makes it clear that attraction between pairs of quarks is not enough to explain the strong force. The colors of the quarks are continually changing and adjusting, while gluons keep them in balance so that their net color remains white. This responsiveness is required to create the wave function for a proton or neutron. The forces that keep quarks aligned in this way are carried by eight different gluons, each carrying a different set of color charge combinations.

All of the forces that "kick" by attracting quarks happen between pairs of quarks. But the forces that unite the quarks and gluons into a cohesive group and keep them all aligned to create a net color charge of zero are governed by the wave function of the proton or neutron. This is the wave function of the *one* proton or neutron that unites the group. No matter how you slice it, this looks like a case of *strong emergence* with *top-down causation*.

Look again at the significance of what Schumm (2004) just told us:

> In the 1960's…it was found that it was simply impossible to construct…**a wave function that represented the known properties of the proton and neutron.** Only by hypothesizing, with no other motivation than to make these wave functions work out, that quarks carry a novel property known as color…was the quark model rescued. (p. 267) [Emphasis added.]

The wave function for the proton *does* influence the quarks – the foot soldiers on the ground – to stay united as a team. This acts as static forces that carry no energy. However, all the forces that "kick" quarks to energetically attract each other happen at the lower level – between the quarks. Gluons are emitted and absorbed, back and forth between quarks, creating this attraction, but the gluons also attract each other in exactly the right way to form a dynamic responsive interaction that stops working if you take it apart. And the bond breaks down if you take it apart because all of the careful corrections to keep the bond white are governed by the wave function for the proton itself. This means that a wave function that describes the *one*, the proton or neutron, is needed to create the strong all-for-one bond. This is clearly top-down causation!

This is why leaders are so important in organizations, countries, families and companies: They pull together different people to work together in a way that takes advantage of their differences and unites them toward a common goal. This is a dynamic, continuously changing process.

To appreciate the amazing feat that the strong force pulls off, we need to look at a more nuanced picture of what happens inside protons and neutrons. This is a picture that emerges from high energy proton-collision experiments.

It turns out that there are far more than just three quarks in a proton or a neutron. There are literally countless numbers of quarks, often called "sea quarks," that are popping in and out of existence as quark-antiquark pairs. And countless gluons pop in and out of existence in this "sea" as well. (Strassler, 2012a) What is so surprising is that these sea quarks and gluons are involved in the unified group bond. They are not just passing by when they pop in and out; they belong to the team. We know this because all of the sea quarks move with the proton or neutron that they belong to. This means that they are bound to the group. (Strassler, 2012b) To pull this off, gluons must work with these added sea quarks and gluons to include them in the wave function. This wave function represents the proton or neutron that cannot be reduced because gluons carry *forces that influence each other*. Forces that affect other forces can't be reduced, as I said before.

Further, the quarks move at extremely high speeds, close to the speed of light, causing gluons to crash into each other, making more quark-antiquark pairs, according to Matt Strassler (2011). Still, all of the color charges in the sea, even as they transform, combine to a net charge of zero.

Everything happening inside protons and neutrons is so cohesive that, from the outside, we see no sign of what Strassler (2013) calls "the massive pandemonium in matter." Protons don't pulse or change shape. Protons remain stable individual particles with masses that are always the same. Inside, however, the sea is anything but calm. An incredibly complex dance is taking place that is orchestrated with such precision that protons always act as singular individuals. And there is so much kinetic energy involved in this pandemonium that it, along with the binding force that pulls the quarks together, creates 99% of the mass of protons Strassler (2013). The mass of quarks only accounts for 1% of the mass of the proton, and gluons are massless, so they add no mass at all.

This is amazing similar to the incredible dance between thousands of complex proteins, genes, and enzymes in the cellular "sea." They align their work so closely together that they create the body of a unified living cell that retains its behavior as an individual agent until the cell dies. And from this dance we see the added energy that "vitalizes" the bond. The similarity between the massive pandemonium in protons and cells looks stronger and more surprising, the closer we look.

This brings us back to the point that Davies (2006b) made earlier:

> For the physicist, the only causes that matter are, to paraphrase Thomas Jefferson, the ones that kick. Wishy-washy talk of global cooperation is no substitute for observing a real, honest-to-goodness force that moves matter at a specific place.... For emergence to become more than just a way of organizing the subject matter of physics, there has to be a clear-cut example of a new type of force, or at any rate a new causative relation, and not just the same old forces at work in novel ways....
>
> When it is put this bluntly, I doubt if many physicists would hold their hands on their hearts and say they believed that any such forces exist. (pp. 38-39)

Physicists know that the strong force exists. In fact, it has the most powerful kick of any force. This has been verified with thousands of experiments. And it is not caused by wishy-washy global cooperation. Gluons pull off an astonishing feat: they assure that the ever-shifting color charges combine together to make "white." And they keep the inner "sea" working together as a group. This is a force that cannot be reduced to interactions between quarks alone because it is governed by the wave function of the proton itself. (Schumm, 2004, pp. 267-271)

The strong force offers compelling reasons to say that top-down causation is real.

In the previous two sections, I focused on looking for any differences that might invalidate the conjecture that the strong force is the result of all-for-one relationships. This is such an outrageous idea that you would think it would be easy to prove wrong. But everything I have found seems to confirm that protons and neutrons are the epitome of all-for-one bonds: They act as self-contained entities that hide the mystery of their bond because it affects only those involved in the group.

This suggests that *strong emergence* and *top-down causation* do exist. Both the strong force and all-for-one relationships pass these tests. And they do so with extraordinary similarity. Isn't this enough to justify exploring this idea further to see if it helps explain the mystery of life?

However, we still have a long way to go to test this theory. We have just scratched the surface. And this shows how vulnerable our new quantum theory of life is to challenges and being proven wrong. Each problem represents another test that the theory needs to pass. And as we overcome each challenge, we discover more and more details of a comprehensive explanation for how life works. Let's turn to the next test.

5. There Must Be Two Types of All-for-One Bonds

The Lenses-of-Perception Interpretation of Quantum Mechanics (Marman, 2018) is founded on principles of perception that describe how and why sentient agents form relationships with each other. In section 1.3, we saw how this leads to one-on-one *personal* relationships and third-person *impersonal* relationships. The same principles also lead to *all-for-one* personal group bonds.

According to LoP theory, these relationships establish the basis for both symmetry and gauge theory in quantum field theory. And, from these relationships, all tangible phenomena emerge, such as matter, energy, and spacetime, creating the universe as we know it, along with the laws of physics, the four forces, and the different types of particles (Marman, 2016, 433-

465). This offers an explanation, based on principles, for *why* quantum relationships are the source of everything. These principles are consistent with Kastner's RTI model of quantum mechanics (Marman, 2016, section 4) and with quantum formalism (Addendum in Part 1, Marman, 2023a).

One of the founding principles of this new quantum theory of life is that quantum effects only emerge between sentient agents. As I showed in Part 1, section 4, this explains why superpositions act as relationship possibilities. And a wave-function collapse only happens when sentient agents arrive at a shared decision to act on one of the possibilities. Every wave-function collapse involves the transmission and absorption of energy that can be detected by outsiders. On the other hand, superpositions are not directly measurable because they exist outside of spacetime as intangible quantum states shared between sentient agents in relationships.

The benefit of these principles is that they allow us to describe how quantum effects work with such clarity that we can test these principles in countless ways. LoP theory leads to a number of predictions, many of which are surprising. This means that it goes beyond just offering a new interpretation. It opens new doors for science to explore. One of these doors is the possible explanation for how biological life works.

For example, LoP theory tells us that relationships lead to states of anticipation, where *future possibilities* influence choices and shared agreements to act lead to purposeful action. This shows us primitive properties of life taking place at the quantum level. However, this only describes a process for opportunistic action – seeing opportunities and choosing one. There is no thought in this; so, clearly, it falls far short of human actions. Still, it does illustrate acting *for a purpose*, which, up to now, has been seen as an ability that distinguished biology from physics.

But none of this offers a way to explain top-down causation. This is why we need *all-for-one relationships*. Fortunately, LoP principles give us a detailed, precise description for how this must work: A group of sentient agents must make a team by forming complementary relationships with everyone involved. This creates a shared entangled state between each agent in the group and with the *one* who leads. All-for-one relationships create forces of attraction that pull groups together. Working for a higher purpose energizes the team. And the bond inspires everyone to specialize, which reinforces the individuality of each member and makes the team stronger at the same time.

If our model is going to survive, it needs to pass a crucial requirement: Each member must form a personal relationship with the *one* who leads the team. In the case of quarks, it is clear that this *one* is the proton itself, or the neutron. Quarks join together for the sake of the *one*. LoP principles are quite strict about how this must work. To act as a true force, the *one* cannot be just an idea or a vision. A bond must form between sentient agents. This is the only way all-for-one relationships can form.

In the case of living cells, we can see this model working: Proteins, enzymes, DNA, and RNA all work together and specialize for the sake of the cell itself, which acts as a sentient individual. And cells in our bodies act together and specialize for us. If we die, our cells soon die as well. This shows how crucial this relationship is to the *one*.

However, I discovered a problem with this story: We see something different when people come together to form a company. As Greenleaf says, a vision larger than the leader becomes the source of their inspiration. This is what pulls the team together. However, LoP principles tell us that a vision is not enough. There must be someone who acts as a leader. Without a leader, the team has no *one* to rally around. The group falls apart unless someone steps forward to play this role that focuses the team. This also explains why Davies could find no good examples of "whole-part downward causation" (see p. 109). It is not wholeness that calls people to work together, it is working together in an inclusive way that manifests a sense of something larger that feels whole. Therefore, when a leader emerges, we see a *spontaneous break in the symmetry* because the one who steps forward to become the leader is now different from the others. This is essential.

For example, in Dumas' book, *The Three Musketeers*, Athos, Aramis, and Porthos had been living a carefree life that was transformed and inspired by the call to action from D'Artagnan, who acted as the ringleader. D'Artagnan was the receptive-responsive heart of the ring.

Leaders of this kind emerge when they act as servants first. For their own health and the health of their groups, they must also carry a vision for a larger cause. They need to serve both the cause and their groups. This is why we see nested layers in nature acting like fractals, such as the pattern of a fern leaf that is composed of tendrils displaying the exact same pattern as the whole leaf.

However, if we look at this more carefully, we see that, compared to the way cells work together to form a body, something different is happening when an organization forms. When people or animals die, their cells die. The same thing happens when each cell dies: The molecules no longer act as if they are alive because they lose the source of inspiration that vitalizes them. As a result, dead cells quickly decompose. But when a leader leaves a company, the organization simply finds a new leader. And countries change presidents. The end-result of this is that **organizations can live longer than their leaders and their members.**

Thus, there appear to be two different types of all-for-one relationships. This is significant enough that we need to add a new LoP principle to the list in section 1.3:

Principle Six: Personal group relationships between sentient agents can form in two ways – strong and weak: (1) A strong relationship forms when the group is dedicated to only *one* and no other. We see this with protons, neutrons, and living organisms. (2) The group bond is weaker toward a leader who is replaceable.

When I first discovered this, it looked like a problem until I realized that LoP principles offer a clear way to explain why this difference exists. Remember, the bond between team members grows stronger when they specialize. The reason for this comes from the first of the LoP principles: *Perception begins with the sensing of differences* (section 1.3). Physicists have seen this same trait: Quantum entanglement is strongest when shared states are starkly different (Schlosshauer, 2008). In fact, "maximal entanglement" is only possible if the distinction is black and white. It cannot be gray (p. 33). This is why the bond between team members is stronger when they differentiate, and this is also why each quark needs a unique color charge to create a strong bond.

In the case of protons, the sentient agent at the core of the proton works at a larger level that is completely different from the quarks that form the body of the proton. This is a black and white distinction between quarks and their proton. In other words, the emergence of the *one* that is the proton creates a *stark difference*. A stark distinction also exists between the molecules forming the body of a cell and the cell itself. And we see a clear difference between the cells that form human bodies and the beings who inhabit those bodies. According to LoP principles, a stark distinction between the group and the leader is needed to make the strongest type of all-for-one bond.

On the other hand, when a leader steps forward, we see a *small break in the symmetry of a group*. Leaders of people are not that different from those they serve. They are human beings like everyone else. In fact, good leaders emerge naturally from a group when they want to serve the people in their community. This is what makes leaders so valuable.

Kings of old were often seen as being chosen by God. The bond was stronger in those days between them and the people of their kingdom. The "divine right of kings" was accepted when countries first formed because people saw how rare it was for one person to know how to lead a country. Leading a tribe or a team is something that many people can do, but how could anyone pull together dozens of tribes to work together as one? It seemed to require someone blessed by a higher power. Today we know that good leaders are people, not gods. And it is best for everyone if leaders bow out gracefully when it is time for a change. This is why Greenleaf says that it is not the "I" that leads, but the vision itself. The vision is what lives on.

Now that I have explained why there is a difference between *strong* and *weak* forms of all-for-one relationships, and how biology shows us that both types of bond exist, here is the problem: If the above explanation is right, we need to see *weak* forms of all-for-one relationships at the quantum level as well. This is another test for our new theory of life. Fortunately, as surprising as it might sound, there are, indeed, different types of bonds between quarks.

As I said before, a proton is formed by three quarks joining together. More specifically, a proton is made from two "up" quarks and one "down" quark. One of these quarks must carry a "red" color charge, one must carry a "green" charge, and one must be "blue." It turns out that there is another particle that is constructed from the exact same combination of quarks and color charges. It is called the "delta+" particle. However, the bond holding a delta+ particle together is so weak that it decays in far less than a millionth of a second. This shows how much weaker the binding force is. Once again, the strong force matches the way all-for-one relationships work.

For every possible combination of three quarks, there are two different types of baryon particles. One of these types has a stronger bond. The other type decays in less than a millionth of a second. These weak delta-type baryons decay so fast that they act as if they are transitional phases: They exist only briefly before making the leap to the stronger type of bond. In fact, when delta baryons decay, they almost always decay into protons or neutrons. (Schumm, 2004, pp. 192-194) This transition is important, and I will return to it later, because we will see this pattern again.

Physicists have identified a clear difference between protons and delta+ baryons: The total spin of a proton is the same as the spin of one quark, while the total spin of a delta+ baryon is equal to the sum of the spins of three quarks (Schumm, 2004, p. 134 and p. 192). In other words, quarks in protons spin as one, while quarks in a delta+ baryon add together as separate spins. This is an identifying difference between strong and weak bonds created by the strong force, and this fits with what we see as the difference between weak and strong all-for-one relationships. For example, corporations never act as *individuals*.

In organisms, weak bonds play major roles. If our new quantum theory of life is right, the evolution from molecular bonds to the formation of the first living cell is not possible without weak all-for-one relationships acting as transitional steppingstones. And, as I will show later, the process of birth is dependent on the transition from weak to strong bonds as well.

The longest living institutions in human society, such as countries and religious organizations, survive only because they have weak bonds. And the ecology of our planet, sometimes called Gaia, has survived for billions of years only because it is a weak all-for-one relationship.

This means that Gaia is not a being. Gaia is a community. Thousands of people around the world take walks in forests every day to restore their communion with nature. Their bodies calm down and their sense of openness with the world expands, as if they are melting into a larger state of being. Anyone who feels this awe of nature experiences the reality of Gaia. Our bodies feel vitalized by the influence of Gaia. It helps us align with the natural world. However, when we try to exploit nature selfishly, by acting as if we are outsiders of Gaia, then we become more like parasites living off the efforts of others. Acting this way disrupts the ecological balance and the health of the community that we are all involved with. “First Nation” people understood this.

Weak bonds are what make organisms so incredibly complex. Even in the simplest cells we see groups of molecules working together to accomplish amazing feats, such as when a cell divides to reproduce, or when DNA is translated to create new proteins. Groups of molecules act like organs to extract energy from food for the sake of the cell’s life. All this is done by teams of proteins. The cell itself is not directly involved in the actual work. It leads the way when hunting for and consuming food. But the assimilation of energy is done by specialized teams that work for the sake of the cell. Many of these teams are held together by weak bonds, as we will soon see.

Our organs work this same way. Hearts and lungs are not individuals. They are communities of cells. This is why organs can be replaced and kept alive outside of a body for a while.

Denis Noble (2012) shows how beating hearts are led by a small group of pacemaker cells. The charged ions flowing into these cells determine the electrical potential inside each cell. Proteins open and close channels in the membrane to control this flow. The gating of these channels is determined by the electrical potential of the cell itself, creating feedback between the bottom-up influence from the channels and the top-down influence of the cell itself. Noble describes an experiment he ran that validates the idea that both top-down and bottom-up processes are involved:

> The ‘downward causation’ between the global cell property, the membrane potential and the voltage-dependent gating of the ion channels was interrupted. If there were a sub-cellular ‘program’ forcing the proteins to oscillate, the oscillations would continue. In fact, however, all oscillations cease and the activity of each protein relaxes to a steady value, as also happens experimentally. In this case, therefore, the ‘program’ includes the cell itself and its membrane system. In fact, we do not need the concept of a separate program here. The sequence of events, including the feedback between the cell potential

> and the activity of the proteins, simply is cardiac rhythm. It is a property of the interactions between all the components of the system. It does not even make sense to talk of cardiac rhythm at the level of proteins and DNA, and it does not make sense to suppose that there is a separate program that 'runs' the rhythm. (p. 58)

This shows evidence of top-down causation, and, when we account for all of the activity, there is no need to describe what happens as if it is being driven by a program. The result is simply the outcome of proteins working as a team with a sentient cell. A few pacemaker cells set the rhythm for the whole heart. They act as the orchestral conductors of the heartbeat. This team is not controlled by an outside program. If there is a leader, it is one of the pacemaker cells in the small group. This makes it a weak bond. If that one leader cell dies, another steps forward.

According to LoP principles, the difference between weak and strong bonds is clear. It all comes down to the core-identity of the *one* in all-for-one relationships. If someone steps forward to lead a group, this forms a weak bond because the leader is part of the group, like the quarterback on a football team. When the *one* exists at a completely different nested level of life, then this distinction makes it like a god to the group, creating a bond that is much stronger. No one from the group can create a bond that strong.

This "discrepancy" between weak and strong all-for-one relationships reveals a much richer and more nuanced description of how organisms live. We will learn a lot more about this in the following sections. It turns out that the mystery of biological life is mostly a story of weak bonds, and there is a good reason for this.

6. From Protons to Atoms

It might seem as if all this talk about all-for-one relationships is merely qualitative and, therefore, of little value to physicists. This is not accurate, but the reason it might seem this way is because physicists have turned exclusively to mathematical explanations.

Scientists used to say that we need to understand both *how* and *why* things work. However, after quantum mechanics hit the scene, the goal of most physicists changed. The cause of this shift is the baffling behavior of quanta. The most popular interpretation of quantum mechanics (the Copenhagen Interpretation) says that we will never be able to understand why quanta act as they do because the world of subatomic interactions is nothing like the world we live in.

LoP Interpretation disagrees. There are remarkable parallels between quantum behavior and the relationships formed by organisms. And these parallels help to explain both *why* and *how* quantum particles behave. However, for this approach to work, the principles that underlie these behaviors must be descriptive enough to provide functional models. They cannot be just qualitative.

If it is true, as physicists have long claimed, that mathematical laws of nature govern everything, then relying only on mathematical equations makes sense. The Standard Model of particle physics is accurate and carries the weight of countless empirical tests.

But, what if the laws of physics *do not govern* anything? What if these laws are the *results* of how sentient agents form relationships with each other? If this is true, how could we ever reveal the whole story by focusing only on mathematical models? We would miss the hidden dynamics behind personal relationships. LoP Interpretation says that these hidden dynamics offer an intuitive understanding of what *quantum states and wave functions actually are*. This is why a biological perspective can open new doors to help us understand life, instead of relying on physics alone.

Any good scientific explanation based on principles needs to be testable. This is where the power of mathematics shines. There is no better example of this than the strong force and how it creates protons and neutrons. Fortunately, these tried-and-true equations used by physicists seem completely consistent with LoP principles. Further, LoP principles explain *why* gluons are never seen flying around the world, and *why* protons and neutrons appear to spin as one. But the picture gets more complicated when we shift our focus to the force that binds protons and neutrons to each other to create atoms. This "nuclear force" is related to the strong force, but in a complex way.

The mathematical model for how the strong force works, as we have seen, is based on three hidden dimensions. It accurately simulates almost everything we need to know about protons and neutrons, the way gluons work as a team, as well as the way quarks bond together as a group. However, this model cannot explain how the nuclear force binds neutrons and protons together. And the reason it fails is because the color of protons and neutrons is supposed to be white – color neutral. If they have no color charge, how can the strong force be involved? It can't.

In the year 2000, a one-million-dollar "Millenium Prize" was offered to anyone who can explain the "Millenium Problem" of how the same mathematical model that defines the strong force can also define the nuclear force that holds the nuclei of atoms together (Clay Mathematics Institute, 2021). Twenty years later, the million-dollar prize has not been collected. The puzzle remains unsolved.

However, physicists found a way to model the attraction that pulls nucleons (protons and neutrons) together. This new model diverges in important ways from the mathematical beauty and elegance of the strong force model, but physicists are still convinced the nuclear force is related to the strong force. And their new model for the nuclear force is incredibly accurate in describing the forces at work between the nucleons in atoms. This presents another hurdle for LoP Interpretation. Is the principle of all-for-one relationships consistent with the new model? Let's take a look.

To explain the nuclear force, physicists say that there is a slight flaw in the strong force model: When quarks bond together, the net color charge is not completely neutralized. This creates what is called a "residual strong force" (see Strong Interaction, 2023). As a result, protons and neutrons are not completely white. They carry a small bit of color charge. The explanation for why color charges are not exactly zero is that, for some reason, the symmetry between quarks is not exactly the same. A tiny difference – *a small break in the symmetry* – exists between quarks, creating an imbalance. This is another case of "spontaneous symmetry breaking." For some reason that physicists have not been able to explain, up-quarks differ from down-quarks.

LoP principles offer an insight into what may have caused the break in symmetry. We learned in the last section that a small break emerges during the transitional state, when quarks form groups as delta-type baryons before changing into a proton or neutron. Delta-type baryons are not sentient agents, as I said before. Thus, the quarks are held together by only *weak* all-for-one relationships. Protons, on the other hand, are bound by *strong* all-for-one relationships.

If this is correct, then one of the quarks in every delta-type baryon must step forward to act as the leader. This is the only way a *weak* all-for-one relationship can form. This *breaks the symmetry* between quarks. They are no longer exactly the same. In fact, this *must* create a small break in the symmetry between quarks, as I pointed out in the last section, because this is exactly what happens when someone steps forward to lead a group.

Delta+ baryons are made from two up-quarks and one down-quark, the same as protons. So, it makes sense that the down-quark in the delta+ baryon is the one that steps forward, making it different from the up-quarks. The distinction of being a leader in a weak all-for-one relationship is small, so the symmetry between the quarks should only be broken in a small way. But a break in symmetry must happen, if LoP principles are correct.

Physicists say that whatever causes this original spontaneous break in the symmetry ends up producing an "explicit break" that makes the mass of down-quarks slightly heavier than up-quarks. This bit of added mass makes neutrons slightly heavier than protons. And, when two quarks bond together as a pair, which creates a *meson*, they can have small breaks in symmetry as well.

This is where the story gets far more complicated. Physicists say that this spontaneous break in symmetry creates an added layer of three hidden dimensions built on the three-dimensional symmetry of the strong force (see Chiral Symmetry Breaking, 2023). This means that the broken symmetry between quarks results in a tiny amount of residual color charge in protons and neutrons. This residual charge creates the force of attraction that holds protons and neutrons together.

As a result, the nuclear force is far weaker than the strong force. However, the nuclear force is still much stronger than electromagnetism, which causes positively charged protons to repel each other in the nucleus. In other words, the nuclear force appears to be based on the same principles as the strong force, except it is a *weak* version of the strong force.

Does this mean that the bond holding the nucleus together is a *weak* all-for-one relationship? LoP Interpretation offers no other way to explain a weak group bond, making this another test for our new theory. Are atoms formed by *weak* or *strong* all-for-one relationships, or neither?

We can use a number of criteria to see if LoP principles pass this test. First, as I said earlier, when looking at the weak force holding delta-type baryons together, we see that the spin of delta baryons is the sum total of the spins of the three quarks, while the spin of a proton or neutron is the same as the spin of one quark, as if the quarks are spinning together as one. So, the question is *Do atoms spin as one?* or *Do the spins of atoms look like a sum of the spins of the protons and neutrons?* The answer is that atoms do *not* spin as one. This is a well-known property of atoms: their spins are the sum of the spins of the nucleons. Again, this shows a weaker bond.

Second, we know that a major distinguishing feature of strong all-for-one bonds is that the *one* that pulls the group together cannot be replaced. When a human being dies, their cells also die. However, leaders of organizations can be replaced, allowing organizations and institutions to live far longer than their leaders.

How does this relate to the nuclear force? It means that, if the force that holds protons and neutrons together is the result of *weak* all-for-one relationships, then atoms must be free to change leaders. All atoms with more than one proton have a half-life. They decay when one or more protons leave. If a leader leaves, a new proton needs to step forward to become the leader of the nucleus, and protons and neutrons must be free to rally around that new leader.

Quarks do not have this freedom in protons and neutrons. They cannot leave. Only powerful high energy collisions can break a proton apart. But when this happens, even then, quarks form new bonds so quickly that quarks are never seen on their own. That is truly a *strong* bond.

Thankfully, protons and neutrons are not bound to each other so strongly. They are free to follow new leaders, which means they are also free to join new atoms. In fact, the process of nuclei joining together, which produces new, larger, atoms, creates the radiant light of stars. This process, called fusion, releases energy and creates larger atoms, such as carbon and oxygen, that are crucial for biological life.

This is interesting because, if you remember Niels Bohr's comments in Part 1, (Marman, 2023a, p. 19), he said that one of the differences between atoms and living cells is that atoms roam freely, while cells cannot survive if they are taken out of their habitat. Quarks *cannot* roam freely. But protons and neutrons in atoms *can* because they're bound by *weak* all-for-one relationships. Atoms survive changes in leadership because they are communities, not sentient individuals.

So far so good, but we have more distinctions to consider. The next big difference between the nuclear force and the strong force is that the force binding protons and neutrons together drops off rapidly with distance. Remember, the strong force that binds quarks stays constant as quarks move apart. Does the nuclear force stay constant or drop off with distance? According to physicists, it drops off with distance because the particles that carry the nuclear force are *mesons* that decay quickly. And they decay quickly for two reasons: First, they are composite particles, so they fall apart. And second, they have mass. They are not massless like gluons.

This is where the Standard Model for the nuclear force breaks from the pure mathematical theory that underlies the strong force. Force-carrying particles should be massless, but mesons have mass. This is the "mass gap" problem at the heart of the million-dollar Millenium Prize.[2] Physicists believe this mass emerges because the symmetry between quarks is broken, but they can't prove this based on the mathematical theory alone. However, they are confident that the force-carriers gain mass from a spontaneous break in the symmetry because the results describe the forces holding nuclei together so accurately. Hundreds of experiments have confirmed this.

This change in the behavior of the force-carrying particle gives us a new way to compare *weak* all-for-one relationships with strong bonds. It tells us that the particles that carry a weak bond should have mass. Is this always true?

[2] The mathematical model that defines the strong force is based on "Yang-Mills" theory. This theory works beautifully for describing how quarks combine to form protons and neutrons, but not for how protons and neutrons bond together to form atoms. In the first case, gluons, which are massless, carry the bonding force. In the second case, the particles that carry the force that bonds neutrons and protons together are not massless. This doesn't fit with Yang-Mills theory, creating the "mass gap" problem.

The best way to test this is to find cases in biology where individuals join together, like protons and neutrons, to form *organizations that are not individuals*. Here is an example: when cells work together to form organs in multicellular creatures, like animals. Organs do not act like individual beings. They act like communities of cells that work together for a common purpose.

Now, let's look at the binding forces that hold organs together. Do the forces get weaker over distance, or are they constant? Are the force-carrying particles composite particles with mass, or are they massless?

As you will see in the next few sections, biologists have studied the development and control of organs in great detail. How do cells work together as a heart or lung when all of the cells are clones? Their genes are the same, no matter what organ they belong to. The process that influences DNA to turn on or off certain genes in just the right way to make the cell suitable for an organ is called "epigenetics." This is how heart cells differentiate from lung cells and skin cells. Proteins are the carriers of the epigenetics force, and it is clear that these proteins are composite molecules that have mass.

This describes how the behavior of cells is modified and how they break their symmetry with other types of cells in the same way quarks break their symmetry when forming weak bonds. What we now need to see is how organs work with each other. This is controlled by different types of complex molecules, called hormones. It turns out that this leads to one of the most powerful new insights into how life works in multicellular organisms.

7. Weak Linkages Govern Embryo Development

Biologists Marc Kirschner and John Gerhart (2005) describe how hormones carry signals from one organ to guide the actions of other organs:

The hormone, glucagon, for example, is made in the pancreas and released into the bloodstream that carries it to the liver. This acts as a message from the pancreas to the liver that it is time for the liver to break down glycogen into glucose. This is one of the ways the sugar level in our body is controlled. But glucagon does not interact directly with the enzyme that breaks down the glycogen into glucose. In fact, glucagon, the messenger, does not even enter liver cells; it simply latches on to a receptor cell on the surface of the liver. (p. 137)

If this is already starting to sound complicated, just wait; we are just getting started. It turns out that this receptor sticks all the way through the wall of the liver cell. When glucagon, the hormone messenger, arrives, the receptor cell activates a protein inside the cell. This protein has a weak effect that is just strong enough to start a second process that is waiting to be turned on. This second process influences an enzyme that produces a small molecule inside the cell called "cyclic AMP." Cyclic AMP spreads everywhere. When it finds a second type of enzyme, that second enzyme modifies a third enzyme. This third enzyme is the one that helps break down the glycogen to produce glucose. (p. 137)

Don't worry about how complex all of this seems. The point is a simple one: This is how our organs send hormones as weak messages to each other when a change is needed.

Kirschner and Gerhart (2005) call this series of interactions "a cascade of weak linkages" because all of the reactions simply *influence* the next reaction. Kirschner and Gerhart explain why it is important that one weak force influences the next: *This makes the whole process much more flexible.* If the heart starts beating rapidly, for example, and needs more glucose, other organs, besides the pancreas, can send out messengers that increase the level of cyclic AMP by influencing a completely different cascade of weak linkages. As a result, our bodies have been designed to have "an extraordinary capacity for physiological and evolutionary adaptability." (p. 137)

All of the "signals" sent are carriers of forces that activate proteins and enzymes in other organs. These carriers are proteins and enzymes themselves. Thus, they are all complex molecules. None are individuals. They are composites – more like communities of molecular chains. And they all carry mass.

This is how the organs in our bodies influence each other through "weak linkages" that trigger other cells "just enough to stimulate an already poised process" (p. 137). In other words, they are not on-off control mechanisms. They act more like conductors leading a symphony. This is exactly what we are looking for.

This shows us how *weak* all-for-one relationships can act as top-down influences that lead the organs of our body to do what is needed to sustain life. Kirschner and Gerhart (2005) go on to explain exactly what the term "weak linkage" actually means, making this message clear:

> In molecular terms, weak linkage has two rather unrelated meanings. In the first, it means that the linkages are easily reconfigured because the physical interactions between components are not unique or highly specified. (p. 136)

The molecules are easily reconfigurable because they are open to a wide range of influences. This means they are free to change leaders. The proteins and enzymes do not force what should happen, they simply stabilize a process when it needs to slow down, or they encourage an already existing process that is waiting to be enabled.

The second meaning, which is also often true,

> is that the interactions of the proteins with one another or with DNA are energetically weak compared to "strong" structural interactions among proteins like the collagen subunits that make up cartilage. (p. 136)

In other words, the influences are literally weak, creating unstable interactions. Many processes in our bodies are regulated in exactly this way. All of this confirms that the reactions being turned on or off are not dictating what they do; they only influence the outcome. Both of these meanings add some validation to the idea that these are *weak* all-for-one relationships.

However, this point is so important that it is worth exploring another example to see the magnitude of what this means. Kirschner and Gerhart describe the core processes that guide the development of an embryo from a fertilized egg cell. This is one of the most baffling mysteries of biology that scientists have been trying to understand for more than a hundred years. It was a shock to biologists to learn that weak linkages play the central role:

> How does a single cell, the fertilized egg, with a single genome, give rise to many different cells in the embryo and adult? How does each cell type produce a unique set of proteins for its unique function?... (p. 122)

> Two extreme views of information transfer have always existed in biology, the permissive and the instructive. The distinction comes up whenever there is a stimulus and a response, or more generally a cause and an effect. For a particular response or effect, how much information is provided by the stimulus, the seeming cause, to get an effect? Watering a seed provides a stimulus, but it is a permissive input, since no one would assume that the water falling on the seed instructs the seed how to germinate into a plant…. (p. 125)
>
> It seemed unlikely to many biologists that the signals of embryonic induction could act permissively. The outcome of embryonic induction is, after all, extremely complicated; it results in creation of virtually the entire organized embryo, with hundreds of cell types and many organs, including the entire nervous system, all in the right places.... To everyone's surprise, embryonic induction turned out to be a permissive process; the organizer provides a signal of little complexity…. (p. 126)
>
> What might have been the alternative to permissive signaling? … DNA or RNA might have been passed from signaling to responding cells, "instructing" them on the next steps of development, providing information utterly outside their ken. Alternatively, signals might have been released as a complex spatially arranged code [to direct and control when and where development should take place]. Or enzymes might have entered the cell and there carried out new transformations. These alternatives have never been found to occur. Signaling molecules exchanged between tissues seldom do more than stimulate or block a preexisting process, much like enzyme induction. (p. 127)

The point of all this is that the development of the embryo from a fertilized egg is not *driven* by an instructive process. There is no master blueprint or program in the DNA, nor anywhere else in the body, that controls the development. Everything is influenced by weak linkages. This gives rise to a new term, *induction*, to describe this influence, rather than force or driver.

The "organizers," *leading* the way, *induce* needed processes by sending molecular signals that simply say, "a bit more of this" or "that is enough." The organizers act as conductors of the symphony. The cells do all the work and know what they need to do. And organs also influence each other the same way. This means that the communities we call *organs* are also in relationships with each other through weak linkages. Hormones act as messengers between organs. This is why organs act receptively and responsively to each other.

As a result, there are countless feedback loops with signals, carried by enzymes, that ripple across the tissues *inducing* the embryo to develop spontaneously into specialized organs and hundreds of cell types. If no program or blueprint "instructs" the process, then where does the plan come from?

Do the hormones and enzymes carry the inspiration to develop, leading the cells and organs to work together for a larger goal? Are the hormones and enzymes empowered by *what is possible*? Is this how the development of an embryo works, without any program controlling the process?

Do you now get a sense of how a new quantum theory of life can, indeed, paint a rich new picture of organisms and how life forms are built to originate behavior from within? All-for-one relationships may be the answer. In the following sections, we will find some answers to the above questions, showing, in detail, why it does make sense to suggest that weak all-for-one relationships are the *leaders* of these processes that are not driven; they are *induced*.

8. The Amazing Case of Mitochondria

The comparison seems to hold up between the force pulling the nucleus of atoms together and the weak linkage that induces organs to work together. But, if we want to complete the test, we also need to find cases in biology where we see strong all-for-one relationships between sentient agents and a distinctly different *ringleader* that is also sentient, such as how quarks bond together to form protons and neutrons. This means finding individual organisms that work together as a team directly with a higher-level organism that is also an individual.

I could find only one example in biology where this seems to apply: the organelles, such as mitochondria, in the cells of multicellular organisms. Mitochondria act as "powerhouses" for cells in animals, plants, and insects. Biologists agree that mitochondria were once bacteria that, for some reason, came to live inside an "archaea" cell (another type of single-celled organism). The bacteria formed a symbiotic relationship with their new host cell, creating the all-for-one relationship we are looking for. But this leap in evolution was an extraordinary event, according to Lane (2015).

> There is a black hole at the heart of biology. Bluntly put, we do not know why life is the way it is. All complex life on earth shares a common ancestor, a cell that arose from simple bacterial progenitors on just one occasion in 4 billion years. Was this a freak accident…? We don't know. We do know that this common ancestor was already a very complex cell. It had more or less the same sophistication as one of your cells, and it passed this great complexity on not just to you and me but to all its descendants, from trees to bees. (p. 1)

The big problem with this event is that most evolutionary biologists are convinced that this could not have been the product of evolution. This is why Lane asks if it was a freak accident. What could possibly cause a group of bacteria to give up their independent lives so that they could work together inside of an archaea cell? Our new theory of life says that this is not as extraordinary as it sounds because all-for-one relationships offer big advantages: they increase the flow of life to everyone involved in the bond.

However, this step was only a *weak* all-for-one relationship. The archaea cell stepped forward to take the lead. Up until then, all the cells on our planet were simple single-celled organisms, called "prokaryotes."

This is not what we are looking for, and this is not the momentous change Lane is talking about. Remember, weakly bound quarks make delta+ particles that change into strongly bound protons if, and only if, the proton is sentient and takes the reins. We see the same shift taking place in the emergence of multicellular life. The group began as a team of single-celled partners working together. For some reason, the group leapt from this weak team-bond to become the first of a completely new type of cell, called a "eukaryote." It is called a eukaryote cell because it has a clearly defined nucleus, showing us the nested nature of all-for-one relationships.

All complex life forms, including plants, animals, insects, protists, and fungi, are made from eukaryotic cells. The amazing traits that all eukaryotes possess today – such as sexual reproduction, the ability of cells to specialize, being able to work together as a team to form the body of a larger organism, and the willingness of cells to die to keep the species alive – all came from this common ancestor billions of years ago.

If there are big advantages for these traits to evolve, then why didn't prokaryote bacteria evolve these traits? If natural selection helps eukaryotes, why not bacteria? Lane believes he has the answer to this mystery: Eukaryotes needed to develop a completely new level of complexity – a new cellular structure. A huge increase in energy efficiency was needed to enable these advanced abilities. This transformation was so difficult, with so many hurdles to cross, that Lane believes it was successful only once on our planet.

According to Lane (2015), it all comes down to energy efficiency, and he makes a strong case to prove his point. This gives us one of the answers we are looking for.

Prokaryotic cells, such as bacteria and archaea, are quite different and even more efficient. In fact, Lane says that prokaryotes are about three times more energy efficient per gram than eukaryotes. Unfortunately, the energy-gathering system used by prokaryotes is not scalable.

> Let's expand our bacterium up to the average size for eukaryotes, and calculate how much energy it would have to spend per gene then. You might think a larger bacterium would have more ATP [cellular energy units], and indeed it does; but it also has a greater demand for protein synthesis, and that consumes more ATP. The overall balance depends on how those factors interrelate. We calculated that bacteria actually pay a hefty penalty for being bigger; size does matter, and for bacteria, bigger is not better. On the contrary, giant bacteria should have 200,000 times less energy per gene than a eukaryote of the same size. (pp. 172-173)

This is the first confirmation that we are on the right track. Remember the difference between the strong force and the nuclear force? In protons, the force between quarks does not diminish with distance; in atoms it does. Thus, when the nuclei of atoms get too big, they become unstable, and this is what causes radioactive decay. The force holding large atoms together becomes too weak. This limits the number of protons and neutrons in an atom.

The same thing happens in prokaryotic cells. They gather energy through their membrane and, as long as the cell volume is small, this works fine. But, as the cell grows, a big problem emerges.

This is the major breakthrough that eukaryotes made: They scale up by simply adding more energy producers – mitochondria. For example, liver cells often have thousands of mitochondria because of all the work the liver needs to do. This overcomes the barriers to size – as if distance makes no difference. Mitochondria make energy production scalable.

Therefore, in eukaryotic cells, where nested all-for-one relationships exist between the mitochondria that produce energy and the cell itself, distance does not matter, just as in protons. The energy-gathering process in prokaryotes is different. It relies on proteins and enzymes, which are teams, not individuals. In prokaryotes, distance does matter, the same as with atoms.

This is a remarkable bit of validation, but there is more. Mitochondria are not weakly bound groups of molecules; they have their own genomes. Their genomes show strong resemblances to the bacteria from which they originated, but most of the genes dropped off after millions of years because they were no longer needed. The eukaryote's nucleus has taken over most of the main functions. Thus, mitochondria have become highly specialized. They now only focus on one job: powering the cell. Once again, specialization is a product of all-for-one relationships.

When it comes time to reproduce, in many cases new mitochondria divide to make copies at the same exact time that the nucleus of the eukaryote divides. This shows how extraordinary the level of cooperation is between the cell's nucleus and its mitochondria. They work together as *one*. In fact, if they get out of synch even slightly, it can create severe problems in cellular health. (Lane, 2015, pp. 238-251) This suggests an extremely strong bond. More validation.

If the relationship between mitochondria and their eukaryote cells form the same strong bond that we see between quarks and their proton, the eukaryote cell and mitochondria must all be sentient. Everyone agrees that eukaryotes are alive. They clearly act as individuals, and they have the ability to originate behavior. Mitochondria are more of a challenge.

Most biologists say that mitochondria are no longer alive because they cannot live on their own. But this criterion is flawed because no organisms possess life by themselves alone. If you take creatures out of their habitat, they all die.

However, in this case, the *inability* of mitochondria to live on their own is exactly what we are looking for. If they could, they would fail the test. Remember, quarks cannot live on their own either. When animals die, so do their cells. This is the most important sign of a *strong* all-for-one relationship, and this is exactly what we find with mitochondria.

I find it interesting that organelles, such as mitochondria, are the only cases I could find where there appears to be a *strong* all-for-one bond between life forms. *Weak* relationships are the rule in biology. Mitochondria and other organelles are the exception because most organisms do not want to give up their lives so completely. Freedom and the ability to live with a bit of independence is too important. Also, when it comes to forming a relationship with our body, it is not our cells that we get to know personally, it is our organs that we relate to; our stomach, heart, and brain, which are all groups, not individuals.

However, I did find one other example that comes close. I wondered about social insects, such as bees and ants. The bond they form with their hives seems incredibly strong, almost as if they are in continual touch with the hive consciousness. And they do nothing but what the hive needs, as if their individual lives have been surrendered to the hive. Could hives be sentient individuals?

The first thing we need to ask is whether bees can live without their hive. It turns out that drones cannot. Without honey to sustain them, they drop dead in hours. A worker bee can live until the supply of nectar in their stomachs runs out. A worker bee usually lasts for only about 40 minutes on the supply they have. However, they *can* replenish their supplies by visiting flowers. Worker bees are designed to go out and gather nectar, so they clearly have more freedom. Still, when the weather turns cold, drones and worker bees can only survive by huddling together and living off the supply of honey. They die without the hive. (Thornton, 2017)

This sounds fairly close to what we are looking for. However, the story changes when we look at the queen. She is starkly different from all the others. A newly born queen bee mates with a dozen or more drones, gathering enough sperm for all the eggs she will need to lay to start a new hive. Queens then burrow down to hibernate for the winter. (Thornton, 2017)

In other words, a queen *can and does* live without a hive. This tells us that she is *not* dependent, while all the other bees are. As a result, this comes close, but it still appears to be a weak bond.

To test this further, I wondered: *Are hives able to grow without bounds, or are there limits to the size of a hive?* The answer is that when a queen runs out of room to lay eggs, she leaves with a swarm of drones and worker bees to start a new hive. (Thornton, 2017) We see, again, that distance does matter, limiting the size of a hive. Thus, it appears to be a weak all-for-one relationship.

This leaves the question: Why do beehives seem so much stronger than most communities? Our new model offers an interesting answer. Queens are born like other worker bees, but they are fed royal jelly. This transforms them into queens. (Cowman, 2017) This *break in symmetr*y makes them dramatically different from all the other bees, making the hive bond stronger. However, queens are still bees, after all, and they live with all the others for the sake of the hive. She is actually "servant first." She does not control the other bees. The life of the hive, however, revolves around her.

This illustrates how a new science of quantum biology can help us distinguish between groups of sentient agents that are weakly bound, compared to organisms that are strongly bound because they are individual sentient agents. It is not always easy to tell the difference because, as Niels Bohr said, there is no way to detect sentient agents (Marman, 2023a, p. 20). We can only see the actions of their bodies.

However, the role of all-for-one relationships and their connection to the strong force still holds up. And this force, acting as an influence, induces the processes of life by their ability to anticipate what is possible. Calling this the *life force* does make sense.

9. Bridging the Chasm between Molecules and Cells

This brings us to another major challenge for a theory of life. In trying to explain the origin of life, scientists have generally favored two main conjectures: the RNA-First, and the Metabolism-First hypotheses. Both suffer from serious problems, as Walker and Davies (2013, pp. 2-3) explain in detail. LoP theory offers a new approach to solving this daunting mystery. It agrees with Walker and Davies (2013) that the origin of life is driven by a fundamental change in the way information is used.

> Although it has been notoriously difficult to pin down precisely what is it that makes life so distinctive and remarkable, there is general agreement that its informational aspect is one key property, perhaps the key property. The unique informational narrative of living systems suggests that life may be characterized by context-dependent causal influences, and, in particular, that top-down (or downward) causation – where higher levels influence and constrain the dynamics of lower levels in organizational hierarchies – may be a major contributor to the hierarchal structure of living systems. (p. 1)

We now have important new pieces to help us with this puzzle: All-for-one relationships open the door for sentient agents to operate at larger nested levels and lead actions at lower levels, creating "strong emergence" and "top-down" influence. However, while we see possible signs that this behavior is present at the level of atoms, it is only in an extremely rudimentary form.

Even the simplest organism reproduces, hunts for nutrients, and protects itself from threats. These abilities require such sophistication, complexity, and purposeful action that simple single-celled bacteria seem far closer to human beings than to atoms. This shows how big the gap is between physics and biology. How do we bridge this chasm?

Our proposed theory says that cells are able to act as sentient agents because they have strong all-for-one relationships with the proteins that form their bodies. This is why proteins, enzymes, and DNA display no signs of biological life outside of living cells. And the flow of life ends when a cell dies, or when these molecules are removed from the cell and placed in a test tube.

On the other side of the chasm, we see protons and neutrons created by the strong force. They then make atoms through a weak version of the strong force, called the nuclear force. These strong and weak versions of the strong force closely match the behavior of strong and weak all-for-one relationships.

Atoms then join together, creating all kinds of chemical compounds. But the molecular bonds that hold atoms together are almost always the result of electromagnetic forces, not the strong force.

If our new theory of life is correct, there *must* be situations when molecules join together to form weak all-for-one relationships. In other words, before the first cellular organism could emerge with top-down causation, a crucial requirement had to be met: Molecules needed to develop weak all-for-one relationships to bridge the gulf between atoms and cells. This suggests that it was not metabolism or RNA that crossed the chasm to organic life because, as Walker and Davies (2013, pp. 2-4) show, neither metabolism nor RNA enable the ability to deliver causation from a larger level. **Only molecules that form weak all-for-one groups could have created a path to cellular life.**

All the living cells we see today were born from other living cells. Reproduction is the result of “multiplying by dividing,” giving birth to new cells. But cellular division was not an option before the emergence of the first cell. The process leading to the first cell had to be different.

The question we need to ask now is this: Are there any signs of weak all-for-one relationships in this chasm between atoms and cells? In other words, can we find evidence of molecules that work together for a larger future possibility – outside of cells – where one molecule steps forward to act as a leader?

This presents another major challenge for our new theory of life because nothing in physics or chemistry suggests that either the strong force or the nuclear force are active in this way beyond the realm of atoms. Fortunately, a potential solution does exist, but it requires a radical new interpretation of the well-known process in chemistry called *catalysis*.

Catalysis has been studied since the early 1800’s (Robertson, 1975). Today it is an important part of chemical engineering because chemical reactions accelerate significantly when a *catalyst* is added. About 80% of all industrial chemicals are produced through catalysis because it is so much more efficient.

What distinguishes catalysis from all other aspects of chemistry is that it does not affect the energy released by a reaction. Instead, a catalyst reduces barriers that stand in the way of a reaction.

Figure 1 on the right shows that there are almost always obstacles standing in the way of reactions. Energy is needed to overcome these barriers. However, when a catalyst is introduced, far less energy is needed. Or, with the same amount of energy, the reaction happens quicker. Often, much quicker. Catalysts can accelerate reactions by up to 10,000,000,000,000,000,000 times faster! (Garcia-Viloca et al., 2004, p. 186)

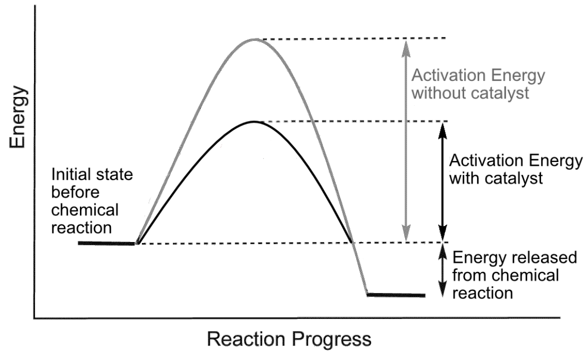

Figure 1. Chemical Reaction Energy Profile
Catalysts reduce the activation energy needed to initiate chemical reactions. Catalysts *do not* affect the amount of energy released by reactions.

Think about what drives a chemical reaction: Molecules react when they find a chemical pathway to a lower energy state, releasing energy in the process. Or they react when energy is absorbed. But most molecular reactions have obstacles that inhibit the process. This is especially true for the complex molecules we see in organisms – they face far more barriers. In fact, almost all of the reactions needed for life in living cells are impossible without catalysts.

To understand what this means, picture a lake on top of a mountain that is surrounded by dirt and rock barriers that prevent the water from flowing down. Energy is needed to create an opening in the dirt walls. But as soon as the opening is created, water starts spilling through. Otherwise, water seeps through the earth very slowly.

When a catalyst enters the scene, suddenly the dirt walls are removed and the reaction bursts into action. The "activation" barrier is not just lowered – it is often removed almost completely. This is what happens when chemical reactions are led by catalysts.

Can catalysis be the result of weak all-for-one relationships? Even when I first asked this question, I saw compelling reasons to suggest that it might be. For example, when a group works well as a team, many of the usual obstacles disappear, making work flow much faster. Plus, when working for a meaningful purpose, the team feels empowered by a sense of added energy.

This brings us to the most significant distinguishing principle of catalysis: After the reaction is over, the catalyst emerges *unchanged*, as if it was not involved. This is strange because molecules involved in chemical reactions *are* transformed by the process into completely different molecules. They are clearly *changed*. But when the smoke clears, it looks as if the catalyst did nothing.

Even more amazing, catalysts add no energy *to*, nor absorb any energy *from*, the reactions they are involved in. This is unique in chemistry. Only the process of catalysis acts this way.

The process of leadership is similar. Good leaders exert no force on team members. In fact, leaders may not be involved in doing the work itself. They feel inspired by the possibilities, and this inspires the team. Thus, leadership plays no role in the energy expended to get the work done, as employees often complain. But leaders clearly help accelerate the work in the same exact way as catalysts. In fact, it makes perfect sense to think of leaders as catalysts. Many leadership trainers make this exact claim for good reasons.

This conjecture that catalysis and leadership are based on the same exact principle is, of course, a wild one. However, the question is, does it hold up under detailed analysis? Let's see.

First, which type of all-for-one relationship could catalysts use – weak or strong? The answer to this is clear: It is weak because reactions that are accelerated by catalysts often change leaders. After one reaction is over, a new catalyst often steps forward to lead the way through the next phase of the reaction. This is exactly what happens in organisms.

Enzymes, acting as catalysts, bring a preliminary round of changes. New enzymes then enter the scene to take the transformation further. This is what we saw in the process of embryo development. Wave after wave of catalysts guide the way, like specialized leaders taking turns. Each enzyme fulfills a specific need toward a truly large-scale, inspirational possibility – the flow of life. Remember, there are no explicit programs or instructions that direct embryo development, as we saw above. But there are hundreds of guides leading the way, step by step.

Second, if catalysts use a *strong* all-for-one relationship, then removing an enzyme from a living cell and putting it in a test tube would end its catalytic ability. This is not what happens. This was discovered in 1897, when Eduard Buchner first extracted enzymes from yeast cells. He showed that they continued their work of catalyzing the fermenting process. (Punekar, 2018, p. 8)

> Jons Jacob Berzelius was the first to define the term "catalyst" in 1836. In his view, a catalyst was a substance capable of wakening energies dormant, merely by its presence. He was also the first to recognize the similarity of catalysis in a chemical reaction and inside a living cell.... Those were the times when a "vital force" was associated with living cells and biocatalysts were part of this explanation. Only much later did the concept take root that ordinary physical and chemical principles apply to enzyme catalysis....
>
> The vitalistic theory was firmly laid to rest with Eduard Buchner's conclusive demonstration that a suitable extract from yeast cells could convert sucrose to alcohol. This was revolutionary in 1897 since fermentation was shown to occur "without living yeast" for the first time. (Punekar, 2018, pp. 7-8)

If catalysts cannot work outside of living organisms, there would be no way catalysis could bridge the chasm between atoms and the emergence of the first cells. This shows us conclusively that, if enzymes and other catalysts use all-for-one relationships, they must use the weak type. However, this also suggests that catalysts may, in fact, create a weak "vital force" – or perhaps it is better to call it a "vital influence" – as a precursor to cellular life.

Here is another test: Distance matters. This is another sign of weak all-for-one relationships. For catalysts to act, they must be in *close* contact with the "substrate" molecules involved in the reaction. As we will see, the intimate relationship between the catalysts and the substrates is imperative for the reaction to speed up.

9.1. The Catalyst-First Hypothesis

If we want a new name for the origin-of-life theory being proposed here, we can call it the "Catalyst-First Hypothesis," meaning molecules that formed weak all-for-one relationships came first, before the first living cells could emerge. If this is right, and if this is the key to the origin of life, then there must be an ancestral lineage of catalysts that bridge the chasm, all the way from simple atoms to the complex enzymes we find in living cells.

It turns out that there are, indeed, individual atoms that work as catalysts. Many metals are catalytic. For example, William Martin and Michael Russell (2003) say that iron and nickel were both present in the early ocean (p. 65). Metals could have been the first catalysts in the origin-of-life process. And, from a catalyst standpoint, it makes sense that these specific metals were the first step because iron and nickel are simple atoms that *do* act as catalysts.

According to Martin and Russell, the next step took place when hot sulfur flooded the ocean through hydrothermal vents. The sulfur mixed with the iron and nickel to create FeS and NiS (iron monosulphide and nickel monosulphide), which were deposited into small compartments in the hydrothermal vents. These new *molecules* acted as more sophisticated catalysts:

> The naturally arising, three-dimensional compartmentation observed within fossilized seepage-site metal sulphide precipitates indicates that these inorganic compartments were the precursors of cell walls and membranes found in free-living prokaryotes. The known capability of FeS and NiS to catalyse the synthesis of the acetyl-methylsulphide from carbon monoxide and methylsulphide, constituents of hydrothermal fluid, indicates that pre-biotic syntheses occurred at the inner surfaces of these metal-sulphide-walled compartments, which furthermore restrained reacted products from diffusion into the ocean, providing sufficient concentrations of reactants to forge the transition from geochemistry to biochemistry. (p. 59)

Research shows that the early oceans were acidic, and when the heated outflows of metal-rich chemicals flowed out of hydrothermal vents, plumes of complex molecules were created, opening new pathways for chemical reactions. This process – the reverse of metabolism – is accelerated by catalysts, and this produces more advanced molecular catalysts at the same time.

This all fits well with the Metabolism-First Hypothesis. The only difference with our theory is that metabolism is not the driving force towards cellular life. Catalysis is the driver. And the reason catalysis comes first is because it is a quantum process where *possibilities* influence top-down reactions. In other words, the possibility of increasing the flow of life acts as an influence on the molecules that induce the creation of new catalysts that are even more complex. If this is right, then catalysis acts like a weak form of the *strong force* that pulls particles to work together as one.

There is plenty of evidence to support this speculative idea. First, it is clear that removing DNA from cells doesn't kill them; they continue to live. But cellular life is not possible without catalysts. Cells *will* die if you remove all the catalysts. Life depends absolutely on the process of catalysis.

Second, there is strong evidence that quantum processes *are* involved in a common form of catalysis. Hydrogen atoms help carbon atoms bind together in organic molecules through electrical attraction. One common barrier that stands in the way of activating this chemical reaction is breaking hydrogen free, such as breaking hydrogen from its bond to oxygen in water molecules. This hurdle must be overcome in many reactions because it requires activation energy. However, a hydrogen ion is simply a proton. And quantum mechanics says that protons can "tunnel" through a barrier simply by appearing on the other side. No effort is needed. A proton just makes a quantum leap to free itself from the bond. As we will see below, it is well-known that catalysts increase this process of proton tunneling, as if the presence of a catalyst encourages protons to make the leap.

Third, while tunneling is an important aspect of catalysis, the latest research suggests that it is not the most important. It is known to account for up to three orders of magnitude in speeding up reactions. But the most significant processes, which accelerate chemical reactions by more than 11 orders of magnitude, use other ways of removing barriers. (Garcia-Viloca et al., 2004, pp. 193-194)

What are the barriers to chemical reactions that catalysts overcome, and how do catalysts cut through the red tape that stands in the way? How do they inspire protons to make the quantum leap to the other side of a barrier? The following quotes from, *Enzymes: Catalysis, Kinetics and Mechanisms*, by Narayan S. Punekar, offer clear answers from the latest research on catalysis:

> The majority of the enzyme-catalyzed reactions involve one or more proton transfers and, hence, general acid–base chemistry permeates most of enzymology. Almost all these proton transfers are catalyzed. (Punekar, 2018, pp. 62-63)

Moving protons plays a central role in the catalysis taking place in organisms. Protons might be extracted from a molecule, donated to another molecule, or simply moved from one location on a molecule to another. To accomplish this, enzymes use acids to donate a proton. In fact, the definition of an acid is a molecule that easily loses a proton. (p. 64) Bases are the opposite; they attract protons. And this is why they are used by enzymes to extract protons.

But how does adding, extracting, or moving a proton speed up a chemical reaction? An acid or base reaction describes a chemical reaction by itself, but this changes the original molecules into something else. Catalysts, on the other hand, are not changed because they only encourage protons to move in order to speed up the reaction. The *shift* in protons happens much faster when catalysts lead the way. In other words, these appear to be "weak linkages" that influence the reaction.

This only gives us a little peek into the story. We need to dig deeper to see the whole process of catalysis more clearly. Punekar says that enzymes play three major roles: 1) the acceleration of reactions; 2) specificity; and 3) regulation (p. 50). Let's look at these one at a time. All are needed for cellular life.

The first role of catalysts is speeding up chemical reactions. Accelerating the process is essential, as Punekar explains, and this is unique in comparison to all other chemical reactions that simply follow chemical pathways to a state of equilibrium. Catalysts act more like go-between agents that help organisms sustain themselves in a state that is far from equilibrium:

> Enzymes and catalytic phenomena occupy a central position in biology. Life as we know it is not possible without enzyme catalysts. Greater than 99% of reactions relevant to biological systems are catalyzed by protein catalysts.... Enzymes are thus a fundamental

> necessity for life to exist and progress. The key to knowledge of enzymes is the study of reaction velocities, not of equilibria. After all, living beings are systems far away from equilibrium. (p. 3)

Second, enzymes perform another important job called "specificity," which means that they have the ability to perform one very specific job and nothing else. They are highly selective. This allows them to accelerate only the reactions between specific proteins that are needed. Enzymes can be so incredibly specific with respect to which reactions they speed up that they can almost act as switches that turn specific types of reactions on and off:

> Specificity, at the molecular level, is the hallmark of most biological interactions. Molecules like receptors and antibodies specifically interact with their cognate counterparts. But discrimination, while performing catalysis, is of paramount importance to biology and is unique to enzymes! Specificity is a virtue when two similar reactions are to be kept separate, at times in the same compartment....
>
> While enzymes can be highly discriminatory with respect to the substrates they act on, a range of specificity is observed with different enzyme examples. At one extreme they can be absolutely specific, like glucose oxidase that acts on glucose but not on galactose or mannose.... It is fascinating to note that enzymes can be made to discriminate even at the atomic level. (pp. 46-48)

This leads to the third job of enzymes, their essential role in regulation:

> The third important feature of enzymes is their ability to act as regulators in the process of metabolism. [This means that they *lead* the direction of the overall progression.] Marveling at metabolic complexity, Jacques Monod observed that… "condensing what is now known of cellular metabolism we can tell that even if at each step each enzyme carried out its job perfectly, the sum of their activities could only be chaos were they not somehow interlocked so as to form a coherent system." A cell is not a bag of enzymes, and obviously regulating their enormous catalytic potential is a necessity. (pp. 49-50)

Metabolism depends on catalysis. Enzymes accelerate reactions when needed and stop them when they have gone far enough. But they are also involved in activating the right genes to produce new enzymes at the right time, which shows how they also regulate and lead the overall process. This, of course, raises the question: How do enzymes know when it is time to start or stop reactions? For example, think about how crucial timing is during the process of embryo development.

Before we can answer that, we need to understand what the process of catalysis looks like up close. It begins with molecules that are ready to engage in a chemical reaction. These molecules are called substrates. Enzymes pull these substrates together in a way that optimizes their alignment with each other. Molecules are often shaped in ways that interfere with their reactions. Plus, they move chaotically in relation to each other, making it difficult for them to stay aligned. These "conformational" mismatches represent a big part of the barriers that catalysts remove.

Any chaotic motion of the substrates interferes with their chemical reactions. Their independent movements and shapes are the biggest barriers. Enzymes have the ability to bring the substrates together and hold them together through the whole reaction process. This ability is described by many names, such as "coming together," "spatial relationship," "propinquity effect," "orbital steering," "restricted motion," and "loss of degrees of freedom." (p. 53)

This means that enzymes reduce the entropy – the chaos – that stands in the way of a smoothly flowing process of life. Do you remember what Schrödinger said about entropy? He said that a living creature can only stay alive by "continually drawing from its environment negative entropy which is something very positive as we shall immediately see. What an organism feeds upon is negative entropy." (Schrödinger, 2001, p. 71)

According to Schrödinger, living organisms must find a way to reduce entropy. This is the fundamental trait of life. But he thought that this was accomplished by consuming food with negative entropy. **Now we see that one important job of enzymes is reducing entropy.** This is exactly what all-for-one relationships do when they help teams work more effectively. Team members align more closely with each other toward a shared goal. Is this how organisms stay far from equilibrium?

The amazing process of catalysis is accomplished at what is called the "active site" of enzymes. This is generally a small region of the enzyme that acts like a three-dimensional scaffold where the substrates are held close to each other so that they stay and move together. The active site is shaped in such a way that it also limits the way the substrates join together so that they are aligned in exactly the way that is best for the reaction. (Punekar, 2018, p. 54)

> Clearly, on binding to the enzyme active site, the substrate loses many degrees of freedom – it becomes ordered. Recall that entropy is a measure of disorder or randomness. (p. 53)

The active site is also made from molecules that form bonds with the substrates to bring them together "in close proximity and proper orientation." This means that this process of "coming together" starts with the enzyme and substrates as separate molecules, but they end up acting as if they are one loosely bound molecule. (p. 53)

> Any enzyme catalytic group acting on the substrate will now be an intramolecular event. Intramolecular reactions generally proceed much more rapidly than their intermolecular counterparts. (p. 54)

"Intramolecular forces" are the bonds that hold atoms together in a molecule. What Punekar is saying is that the key to catalysis is bringing the substrates into such an alignment that they act as *one molecule*. This is *the most significant function* needed to speed up reactions. Enzymes supply the active site where substrates align, pulling the enzyme and substrates to move and act as *one*.

This is *exactly* the confirmation we are looking for. It gives us a perfect description of the role of leadership in all-for-one relationships. Enzymes lead molecules to go through a reaction process together as a well-aligned team.

A huge barrier is created when individual molecules move independently and chaotically in relation to each other. Far more energy is needed for a chemical reaction to take place under these conditions. This is why it is critical for life that enzymes reduce the chaos, the entropy, by helping the substrates align to each other – so *they move as one molecule*. But there is more. The mystery of catalysis gets even more interesting:

> We note that proximity and orientation of the reactive groups (both the enzyme and the substrates) contribute substantially to rate enhancements. But what tools are employed by nature to gain this advantage? The formation of a non-covalent enzyme-substrate complex is the first step in enzymatic catalysis. Substrates are bound to enzymes by multiple weak interactions – often mediated by van der Waals forces, hydrophobic interactions, and hydrogen bonds. (p. 56)

Hydrogen bonds, hydrophobic interactions, and van der Waals forces are all examples of *weak* attraction. For example, van der Waals forces emerge only when atoms or molecules are *extremely* close. The attraction drops off rapidly with distance. These weak forces of attraction are not nearly as strong as the chemical bonds, like *ionic* or *covalent* bonds, that normally hold a molecule together. They are much weaker. However, these weak influences are still able to hold the substrates and the enzyme together as if they are one molecule.

This confirms that enzymes act like leaders that only influence the outcome; they do not force it. And they act just like the "weak linkages" that guide the processes of embryo development, as we saw in the last section. But, once again, there is more to this story.

The enzyme must find the best way to bring the substrates together and orient them, as we have seen. They often do this using "electrostatics." (p. 65) It turns out that electrostatics are non-local forces that exchange no energy, as I mentioned earlier in this paper (pp. 106-107). This is another clear sign that this is a bond that uses no kinetic energy, just like a leader in all-for-one relationships.

But this is just the first step. The active site does far more than this because it actually "discriminates between the substrate and the transition state." The "substrate state" describes the form and shape of the substrates before they start reacting. The "transition state" is the continually changing process when the reaction takes place. Even though the transition state "is of the highest free energy and is extremely unstable," enzymes lead the way through the whole reaction process. (p. 66)

In other words, as soon as the substrates are pulled together and oriented, the enzyme must continue reorienting the group through the transition state. This transition state is when the highest level of free energy transforms the substrates into final products. And this reaction process that transforms the substrates into final products is highly unstable because high levels of energy begin flowing. The release of this free energy would disrupt the reaction if the enzymes did not continue holding them together through the whole reaction.

More importantly, for an enzyme to move substrates from the initial alignment stage to *the transition state,* the enzyme must morph its own shape and orientation. This is how it leads the substrates through the transition state, while the substrates are transforming into final products.

And the substrates are often led through this morphing process by *electrostatics*. As we saw earlier, static forces are created by the attraction and repulsion that emerge from relationship possibilities. Relationship possibilities then lead to a wave-function collapse where energy is exchanged. This is how enzymes help extract energy from food – the process of metabolism.

What Punekar says next is crucial: The transition state is highly active. The old "lock-and-key" model that biologists used to describe catalysts in the early twentieth century doesn't describe how dynamic this process is. It is not right to think of enzymes as inert mechanical devices because they need to be receptive and responsive to the changing forms of substrates and to the possibilities of what they can become in order to lead the reaction from the beginning to the end.

> Therefore, an enzyme cannot be a rigid structure ("lock for a key") but must exhibit local conformational changes…. Conformational flexibility and mechanical motion of the enzyme protein are thus a necessity. Enzymes may therefore be also viewed as dynamic mechanical devices. (p. 79)

> Local protein motion at the enzyme active site must occur. Consequences of small conformational changes are profound and are easily detected by the discriminatory power of enzymes…. In a large measure, the ability of enzymes to maximize orbital steering contributes to catalysis. Often such conformational changes are barely detectable by the best physical tools…. An interesting question was posed by Koshland – "How small a conformational change is big enough?" …Tiny variations…of 10 picometers make a remarkable difference in the efficiency of enzymatic catalysis. (p. 80)

> Precise orientation of catalytic groups is required for enzyme action. Substrate binding causes an appreciable change in the three-dimensional relationship…around the active site.... Clearly, conformational changes are at the root of feedback inhibition, enzyme activation, cooperativity, etc. (pp. 81-82)

In other words, this is an amazing dance. The substrates and enzymes are drawn together and continue dancing as a group while the substrates are transformed into products produced by the reaction – guided by static forces. This process of catalysis is now called "induction." We heard this same term when exploring how embryos develop. Remember, biologists were shocked to find that such an incredible process was possible without clear instructions controlling each step:

> The outcome of **embryonic induction** is, after all, extremely complicated; it results in creation of virtually the entire organized embryo, with hundreds of cell types and many organs, including the entire nervous system, all in the right places.... To everyone's surprise, **embryonic induction** turned out to be a permissive process; the organizer provides a signal of little complexity. [emphasis added] (Kirschner and Gerhart, 2005, p. 126)

In other words, there are no instructions sent from DNA to control embryo development. There is no map showing how all of the organs must fit together. No proteins transform the cells into nerve cells or heart cells.

> These alternatives have never been found to occur. Signaling molecules exchanged between tissues seldom do more than stimulate or block a preexisting process, much like **enzyme induction**. [emphasis added] (Kirschner and Gerhart, 2005, p. 127)

The possibility of developing the whole embryo is waiting in each cell. Signaling molecules simply *induce* some cells to start the work of heart cells and other cells to specialize as neurons. This pattern of weak all-for-one relationships now looks like the central factor in what makes organisms alive. Catalysts only lead. They do none of the actual work.

Is this conclusive proof? No. But it fits well with our theory that catalysis is enabled by a weak all-for-one relationship. The similarities and resemblances to the dance we find going on inside of protons and neutrons is, I believe, notable enough to consider this a worthwhile direction for further research. Is this showing a weak version of the strong force at the level of molecules? In the Addendum, I describe an experiment that further validates this conjecture.

Before we end this section, I would like to test one more aspect of this theory that catalysts are leaders of weak all-for-one relationships. We found a recognizable feature of all-for-one bonds between human beings and between protons and neutrons: all-for-one relationships grow stronger when they are part of a larger all-for-one bond. This should be true for catalysts as well. Is it?

To pass this test, we should see enzymes accelerating chemical reactions faster inside of living cells than in a test tube. I found the answer near the end of Punekar's book (2018). Let's look at what is known about enzymes "in vivo" (in living cells) compared to "in vitro" (in test tubes). But first, I want to go back to an important point that Punekar makes earlier in his book: **"The transition state cannot be captured or directly observed"** (p. 95).

This should sound familiar. We cannot take cells apart to capture how they stay alive. We cannot disassemble a dynamic team of people to study how all-for-one relationships work. We cannot even find quarks on their own. So, it makes sense that we cannot observe the process of catalysis directly, as well.

Now let's get to the direct answer to my question above: Is catalysis stronger in living cells? Punekar explains the answer here:

> A study of enzymes in vivo quickly moves into the realm of metabolism and complexity (Table 38.3). One could build an understanding of metabolism…by studying individual enzymes one at a time [in test tubes] and then upwardly integrating this in vitro knowledge. In practice this is very complex – collecting such data…becomes immensely difficult. This "bottoms-up" approach is like describing the behavior of a gas by applying Newton's laws of motion to every individual molecule in the system. More often, enzymology in vivo takes a "top-down" approach…. It is important to distinguish between…molecular mechanisms and…system dynamics. The very conditions that…[give us measurable acceleration rates from] enzyme reactions in vitro tend to make it invalid for enzyme reactions in vivo. (p. 497)

In other words, the way enzymes work inside living cells is radically different from how they work in test tubes. Punekar's Table 38.3 summarizes these differences.

Table 1. Punekar's comparison of enzyme systems in vitro and in vivo (p. 497)

	Enzymes in vitro	**Enzymes in vivo**
Variables	Few	Many
Interactions	Weak	Strong
Connectivity	Linear	Nonlinear
Processes	Additive	Associative

Aggregate behavior	Predictive	Emergent
System	Closed, simple	Open, complex

This is the confirmation I was looking for. Although it does not quantify how much stronger enzyme **interactions** are in living cells, it shows clearly that they are stronger.

We also see that the **aggregate behavior** is *emergent* in vivo, while *predictive* in vitro. This emergent trait means that catalysis acts more like a "top-down" process in living cells. Predictive means that enzymes act more like bottom-up processes when in test tubes. This is what our new theory of life predicts we should see, since enzymes form strong all-for-one relationships when they are in living cells. This should make the process *strongly emergent, nonlinear,* and *far less predictable*, which are all well-known traits of life.

9.2. What Guides Catalysis?

This leaves us with the big unanswered question I asked earlier: What guides the process of catalysis? This is the same question we asked about the way embryos develop. Kirschner and Gerhart showed that it is clearly not an "instructive" process. There is no program driving it. There is no central control mechanism. It is all a process of weak influences that induce a spontaneous change. How does this work?

This question goes unasked and unanswered in Punekar's textbook because biological research has not yet discovered an answer to how this works. But the fact that this question was ignored is not the real problem. Look at this point that Punekar makes early in his book:

> There should be – and indeed there is – nothing magical about how enzymes bring about fantastic rate accelerations. They do obey the basic physical and chemical principles but are simply better at it. (p. 43)

He is saying that if you look closely at catalytic reactions in test tubes, it is clear that the many ways enzymes influence substrates to come together makes sense based on well-known chemical properties. Chemists can explain the process step-by-step.

But then, on the very next page, Punekar says this: **"For any reaction to occur, it should be accompanied by a decrease in free energy."** (p. 44)

He is stating here the well-known thermodynamic law of chemical reactions, describing the process whereby chemical pathways flow downhill. They only flow uphill when energy is added. In other words, energy drives chemical reactions. And this does, indeed, explain all of the reactions that catalysts accelerate. But it does *not* explain the process of catalysis. This is a serious matter.

Remember, catalysts do not alter the energy profile of the reaction. They only speed it up. This means that catalysts do not add to or use any of the energy released by chemical reactions. But if this is true, then what causes enzymes to morph their shape and pull substrates together in such a dance that holds them together as *one* molecule through the whole transition process?

If these are basic physical and chemical principles driving catalysts to do what they do, then why don't they follow the same universal law of chemical reactions? Why do enzymes not change and "decrease in free energy" (p. 44) when they dance with substrates as they lead them through the steps of the dance? If catalysis does *not* flow downhill to a lower level, releasing energy by transforming the catalysts into something different, then what induces the dynamic changes that make catalysis work?

We can now offer a possible answer to all of these questions: When free energy is released in chemical reactions, this is specifically referring to *electromagnetic* (EM) energy. This means that it is the EM force that is driving chemical reactions. This is crucial because it explains why the process of catalysis does not alter the EM energy profile of the reaction since catalysis is not driven by the EM force; it is induced by a weak version of the *strong* force. Finally, it all makes sense. And this is the way all-for-one relationships work. This is a completely different force that drives catalysts and enzymes to reduce entropy and pull molecules together.

Leaders serve their team by coaching, inspiring, and helping them realize their potential. None of this takes away any of the actual work done by their team. But influencing their team to work closely together for a higher purpose does help work flow more smoothly. This is a force without energy, as I said before. Plus, it does something crucial: A leader is the carrier of what is possible. This possibility vitalizes the team. With all-for-one relationships, this vitality comes from the inspiring potential of the future. Isn't this what motivates enzymes to continue morphing as they lead the dance through the transition state? Is this not exactly what we see happening in living cells? And, in the way embryos develop? Isn't this why we see added vitality in enzymes working in living cells, compared to enzyme catalysis in test tubes?

The story of life cannot be explained only by how electromagnetic energy flows in or out of a cell. Yes, this *does* explain chemical reactions, but *it is not enough to explain life*. The flow of life is not a story about electromagnetic energy flowing downhill until it reaches equilibrium with the environment, like all other chemical reactions. It is about the strong force pulling groups together for a larger purpose.

> While it may do to explain living beings as open systems that exchange matter and energy with their environment – thermodynamic feasibility alone is insufficient to be living! Kinetic barriers have to be overcome. Reactions with relatively fast uncatalyzed rates, like removal of hydrogen peroxide or hydration of carbon dioxide, also need to be accelerated. Enzymes are thus a fundamental necessity for life to exist and progress. The key to knowledge of enzymes is the study of reaction velocities, not of equilibria. After all, living beings are systems far away from equilibrium. (p. 3)

Living creatures sustain themselves in states that are far from equilibrium. Now we can see that catalysts play perhaps the most important role in increasing order and reducing entropy. In living cells, enzymes are not changed by the downhill flow of electromagnetic energy, even when they are in the middle of intense chemical reactions. And weak linkages between cells and organs in organisms also seem to work the same way through hormones, which are also catalysts. This is why creatures do not deplete their energy until they reach equilibrium with the environment, as we see in chemical reactions. Life forms stave off death. According to this new theory of life, these are all signs of all-for-one relationships – the strong force – at work.

Standard chemical reactions can be explained by quantum theory. What is needed is a quantum theory that explains catalysis. Some quantum models have been developed to more accurately describe how catalysts work, but they are based on ideas that were derived long before quantum mechanics was discovered. As a result, quantum models have only been developed to describe the role of *electromagnetic* forces in catalytic reactions (Bell and Head-Gordon, 2011, pp. 454-455). Are EM forces truly enough to explain catalysis?

A lot more research and testing is needed, but seeing catalysts being driven by the strong force, instead of electromagnetic forces, makes sense and opens new doors to a more complete theory of how catalysis works. We need a theory that arises from principles that are consistent with quantum mechanics. Perhaps catalysts are more crucial to biological life than we realized. Something may, indeed, motivate catalysts to hold substrates together as one molecule. There might be a "top-down" reason that they reduce entropy and maintain states far from equilibrium. And there may be a "nested" reason that explains why we see these same traits in protons, neutrons, and atoms, because this is how the strong force works. Remember what Punekar (2018) said earlier:

> Life as we know it is not possible without enzyme catalysts. Greater than 99% of reactions relevant to biological systems are catalyzed by protein catalysts.... Enzymes are thus a fundamental necessity for life to exist and progress. The key to knowledge of enzymes is the study of reaction velocities, not of equilibria. After all, living beings are systems far away from equilibrium. (p. 3)

How do organisms stay far away from equilibrium? As Schrödinger says, sustaining order is the mystery of life. We now have a theory to consider: All-for-one relationships lead chemical reactions into states that are more ordered. This is necessary to sustain the flow of life. They *reduce entropy* during catalysis. And this happens in over 99% of all the chemical reactions. Can this explain how living systems sustain themselves far from equilibrium? Does this mean that all types of all-for-one relationships also reduce entropy?

As we saw in Part 1 (p. 27), Heisenberg (1958) agreed about the importance of sustained order, but he disagreed with Schrödinger that an order of form is needed: "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)

Isn't the dynamic group bond the emerges from all-for-one relationships a good description of the stability of process that Heisenberg said is needed to explain life? Catalysts may have led the way because they were drawn by the possibility of life. And we see this same mysterious stability of process when embryos develop and when hormones lead organs to work together.

This is all the same function, and it began long before the first living cell existed. I call this the Catalyst-First Hypothesis. It shows that cellular life might emerge from atoms and molecules, it adds depth to the mysterious process of how proteins and enzymes lead the flow of life in cells, and how the process of epigenetics guides the development of embryos to develop into life forms. All-for-one relationships – the strong force – may be essential to life. In the Addendum, I offer the results of experiments that further validate the top-down role that catalysts appear to play.

10. The Invisible Agent: Explaining Birth and Death

We can now see a possible bridge of weak all-for-one relationships reaching all the way from the level of atoms to the complex enzymes found in living cells. Catalysts pull molecules together to act as unified teams, reducing the barriers that speed up reactions immensely. Catalysis guides molecules toward possibilities, vitalizing specific reactions while regulating them for a purpose: to make the flow of life possible. They also reduce entropy, keeping life in a state far from equilibrium.

This leaves us with one last step to complete the emergence of cellular life: How do molecules, led by the process of catalysis, make the leap to a living cell? We now have all the ingredients needed to answer this question. LoP principles say that it must follow the process that transforms *weak* all-for-one relationships into *strong* all-for-one relationships.

First, let's return to the quantum level because the story there is simpler.

Above, we saw the transition from *weak* to *strong* all-for-one relationships when delta+ particles change spontaneously into protons (p. 125). Delta+ particles and protons are both composed of two up-quarks and one down-quark. According to Lenses of Perception principles, the down-quark in the delta+ particle steps forward to become the leader that pulls all three quarks together to act as a unified team (p. 129). This bond, however, is too weak to hold the quarks together for long.

Protons are different from delta+ particles because the bond between the quarks in protons is far stronger. According to our theory, this difference exists because the proton itself is a sentient agent. The proton itself becomes the *one* that all three quarks follow. The attraction is much more powerful when this happens because the proton sentient agent is starkly different from the quarks.

The sentient proton agent lives at a larger level of life compared to the quarks that form its body. This stark distinction transforms the all-for-one bond from *weak* to *strong*. Notice that the quarks do not change. Only the relationships between them change because all of the quarks now share a much stronger bond, and this happens only after the proton becomes sentient. LoP principles suggest that this is how all-for-one bonds transform from weak to strong.

If this is right, then the change from a delta+ particle into a proton means that the down-quark steps aside from being the leader after a new leader takes over the team. That new leader is the sentient agent that is the proton itself. However, this raises a big question: **How does the proton become sentient?** The answer is that a sentient agent inhabits the body of the delta+ particle. This is what changes the relationships between the quarks.

This probably sounds crazy as a scientific explanation. We have just gone from crazy to crazier and stepped beyond the realm of traditional physics. We replaced one impossible problem with another. So, now we must ask: Where does the new sentient agent come from?

These are the sorts of questions that arise because sentient agents are invisible to outsiders. As Niels Bohr said, we only see their bodies, not the agents themselves. If LoP principles are right and sentience is the source of what makes quantum behavior so bizarre, then we need to see that sentient agents are different from their bodies. The good news is that physicists have run into a similar problem before; they just did not know it.

I suggest we approach this question the same way quantum physics does when describing how *virtual* photons cross over to become *real* photons. Many physicists treat virtual photons as nothing more than mathematical symbols that merely act like photons that cannot exchange energy and do not exist in spacetime, making them impossible to detect directly.

Nonetheless, virtual photons play an important role: For example, they explain the static force of attraction and repulsion between electrically charged particles. Let's review this again.

Physicists say that electrons repel each other because *virtual* photons pass between them. But only 0.73% of the time are electrons actually physically repulsed away from each other. In those rare cases, the photon that passes between the electrons is said to be a *real* photon because it carries real energy in spacetime. The other 99.27% of the time, a static force of repulsion exists, but no actualized transfer of energy takes place. In those cases, the photon is said to be a *virtual* photon because it does not exist objectively. (Kastner, 2015, chapter 4)

As we saw in Part 1 (Marman, 2023a), non-local static forces arise from relationship exchanges that exist only in the quantum world (p. 67), while forces that accelerate objects are different because they act *in* spacetime. Thus, static forces that create *potential energy* are different from *kinetic forces*, but there is a clear relationship between them: Before real energy can be exchanged, there must be a buildup of static force. Only after that can *real* photons fly from emitters to absorbers carrying real energy. Therefore, it all begins with attraction and repulsion.

We can see electrical sparks created by electrons flying through the air when static charges grow strong enough. Or a beam of light might be created from a stream of photons. Exchanges of real energy only happen after emitters build up more potential energy than absorbers.

Why is radiant kinetic energy different from static forces? Ruth Kastner (2015) offers an explanation. She says that the mystery comes down to a simple fact: There is a threshold that a virtual photon must cross before it can move from being a mere possibility to a real photon:

> "This number, 1/137 [0.73%], is a very well-known number in physics. It is called the 'fine structure constant'. The fine structure constant is important because it characterizes the strength of the electromagnetic interaction between charged particles.... In this book, the fine structure constant gains an interesting new physical meaning: it expresses the likelihood that a photon will advance from being merely 'virtual' to being...actualized." (chapter 5)

According to Kastner, *virtual* photons cross over from the pure quantum state to become *real* photons. This is when the electrical force changes from static to kinetic energy. The problem facing quantum physicists is how to talk about something that exists outside of spacetime. Many say that virtual photons cannot be real because they cannot exchange energy, but forces of attraction and repulsion have real impacts on our world. How can anything that influences our world be unreal?

Physicists face the same problem we are trying to address. It comes down to this: Quantum states do not exist in spacetime. They exist in other dimensions represented mathematically by "Hilbert space." However, these states have an influence on everything that happens in the real world. If they create real influences, then we should treat virtual particles as being real as well. A group of scientists have addressed this same subject: Kastner, Kauffman, and Epperson

(2018) say that quantum states are real and represent states of "potentia" that exist outside of spacetime, and this is consistent with Heisenberg's claims.

This means that we can treat virtual particles as sentient agents without bodies. Having no body, they exist outside of spacetime. They can engage in the exchange of energy or momentum only after they inhabit a body.

Here is a fact that makes this story even more interesting: Every matter-type particle, such as electrons, quarks, and neutrinos, is said to be surrounded by a cloud of *virtual* particles. This gives every matter particle a body. Without that cloud, electrons, quarks, and neutrinos would have no volume because, according to quantum theory, they are *dimensionless points*. But this is not how matter particles act in the real world. They act as if they have volume.

Physicists found that the only way to describe what is happening accurately is to assume that *virtual* particles form the bodies of matter particles. (Marman, 2016, pp. 462-465) This means that all-for-one relationships are the source of their bodies, just like the bodies of protons and organisms; except, in this case, the particles that form the bodies of matter particles are *virtual* – because virtual particles have no bodies of their own. They may be virtual, but they can still create static forces that surround the matter particles. If this is right, then *all bodies, structures, and forms* are the results of all-for-one relationships.

This gives us a way of picturing how virtual sentient agents become protons: They come from the quantum realm where wave functions and virtual particles exist. This is exactly where sentient agents come from before they inhabit living cells. They start in the pure quantum realm outside of spacetime. This invisible dimension is where sentient agents without bodies exist.

As crazy as this idea sounds, another researcher, who took *a completely different approach*, came to the same conclusion. Frederico Faggin, who led a team to create the world's first microprocessor, had a long and successful career as a technology entrepreneur. He recently turned his attention to the mystery of how consciousness is involved in our world. He began to wonder seriously if consciousness might be fundamental only after struggling, unsuccessfully, to find any other way to explain how consciousness could emerge from the complexity of the brain. He describes the path he took to find an explanation:

> "But the paramecium is a single cell!" I exclaimed. "It has no nervous system! How can just a bag of chemicals process information in such an exquisite manner? How can it reproduce by assembling a copy of itself within itself?" This is not a program that can copy itself within the computer memory. This is akin to a computer assembling another computer like itself within itself – hardware and software included – and then dividing into two complete computers! These are feats no engineer could match today. I concluded that there must be something fundamental going on that we do not yet understand....
>
> The cell…contains many hierarchical organizational levels, all working seamlessly together in unbelievable complexity and with a single purpose. Each part of a cell can interact with very many other parts in both a feedforward and a feedback manner without permanent connections among them. This freedom is unlike any found in a computer, for in a computer the connections of its transistors are fixed once and for all by its designer, and its matter does not move in and out of its physical boundaries....

> Everything going on in a living organism intimates that such a physical structure cannot be completely understood within the logical framework of the classical world, even though much of what is happening can. There are many properties that require quantum physics to be understood.... What we cannot account for classically is the fact that living organisms are conscious and autonomous with probabilistic behavior.
>
> I think it will be impossible to explain life without the concept of consciousness because the two are inextricably linked in ways we have yet to comprehend. A living organism has purpose only because it can "host" a conscious entity and can thus act as a unit endowed with free will, intention, and meaning; properties that cannot arise from a bag of unconscious classical atoms and molecules interacting with each other. I think that consciousness must play not only the role of the "glue" that holds together the unity of the organism, while it constantly changes, but also be the "agent" behind its free-will actions. Life exists in a deep and abiding symbiosis with the environment with which there is a constant exchange of matter, energy, and information in a profoundly dynamic equilibrium where the organism is never the same throughout its lifetime....
>
> In the framework I am developing, conscious entities exist entirely in the quantum world and each one has the qualia perception, comprehension, and free will to direct the physical body which is a quantum-classical structure. The quantum portion of the body interacts with the quantum conscious entity and the classical portion of the body interacts with the classical world of which it is part. The conscious entity is the "self" we really are, though we erroneously believe we are the body. (Faggin, 2021, chapter 7)

Does this seem like a lot to swallow? It is, if we only look at the world as outsiders, because a third-person lens cannot see sentient agents, only their bodies. The agents are invisible. They have no material form – the same as quantum states. And they interact with the world through personal relationships that are also invisible to outsiders, just like quantum states. However, once we get over the shock of this perspective, the idea of birth and death starts to make a lot more sense.

10.1. Birth of a New Cell

With this new lens, we can now describe the emergence of the first living cell.

Remember, before a sentient agent without a body can inhabit a delta+ particle and transform it into a proton, the delta+ particle must exist first. This is why weak all-for-one relationships act as transitional states. The bonds holding them together are not strong enough to last long. We see the same thing with catalysis, which is why, when a catalyst pulls substrates together to act as one molecule, this too is called a "transition state."

This shows us that, before a sentient agent can cross over from the pure quantum world and inhabit a group of tangible molecules as its body, that group must already be functional as a team. A virtual agent cannot pull a group together by itself because, being virtual, it cannot do real work or exchange energy. All of the catalysts and proteins needed to keep a cell alive must be working together as a team before a virtual agent can cross over to inhabit the body.

There is only one influence that a virtual agent can have over a weak all-for-one team of molecules before the agent crosses over: it can offer the "possibility" of being part of a larger world – the world of cellular life. However, this is only a static force that influences the team, as we see with virtual photons. This *inspiration* is the source of the weak bonds that *induces* the catalysts and substrates to work as a group, but the team must do all the actual work.

Now we begin to see what an incredible leap this must have been for the emergence of the first living cell. Clearly, this was a rare event. Everything needed for the cell to live must have been working first, before a virtual agent could cross over. After the transition, the strength of the bond increases dramatically, along with a leap in vitality that inspires and induces all the molecules to work together. Then, for the first time, the cell could last and thrive with a strong flow of life.

It seems likely that any outer sheath encapsulating the cell emerged later, after the bond holding the cell together was truly strong. This sheath frees the cell somewhat and allows it to have more independence, although cells are always dependent on their habitats for food.

This is why it makes sense that the pre-cellular mixture of catalysts and proteins that developed into the first living organism probably assembled as a team inside the small cavities in deep-sea hydrothermal vents, as William Martin and Michael Russell (2003) proposed (also quoted earlier in Section 9.1):

> The naturally arising, three-dimensional compartmentation observed within fossilized seepage-site metal sulphide precipitates indicates that these inorganic compartments were the precursors of cell walls and membranes found in free-living prokaryotes. The known capability of FeS and NiS to catalyse the synthesis of the acetyl-methylsulphide from carbon monoxide and methylsulphide, constituents of hydrothermal fluid, indicates that pre-biotic syntheses occurred at the inner surfaces of these metal-sulphide-walled compartments, which furthermore restrained reacted products from diffusion into the ocean, providing sufficient concentrations of reactants to forge the transition from geochemistry to biochemistry. (p. 59)

What makes this scenario so compelling is not just the presence of catalysts and the natural growth of more complex molecules due to the sources of energy from the heat in the vents and the alkaline-acid reactions taking place. It is the small compartments shielding the molecules inside from dilution by the sea and dispersion by ocean currents.

Small, protected spaces are necessary because it must have taken significant time to develop the right chemistry. First, catalysts needed to increase their complexity to match the complex molecules that were emerging. Then, a community of catalysts and chemicals needed to form and develop weak all-for-one relationships that held together long enough for a sentient agent to cross over and transform the community into a living unit.

There is a possibility of interim stages to this development. Some simple catalytic stages could have crossed over from weak to strong bonds. These transition states, when substrates and catalysts act as one molecule, could have been inhabited temporarily by virtual agents. This would allow the group to hold together for much longer periods of time. However, these would not be living cells because they would not have the degrees of freedom needed to hunt for food or escape threats. They might only, at best, allow the process of catalysis to continue longer than normal. If these interim stages actually did happen, then we should be able to find examples of it happening today, outside of living cells. There are known cases of autocatalysis in chemistry. If the catalysis continues for longer than expected, this could be evidence of these interim stages.

Once the leap from a weak bond to a strong bond took place, and the first living cell existed, it could begin growing organic cellular walls that would allow the cell to free itself from the cave where it was born. This probably did not happen with the first living cell, or even the second or third. There were probably countless generations, developing over a million years, before that happened. This means that the process of reproduction needed to take place first.

10.2. The Beginning of Reproduction

We now have a theory for how the first cell emerged. But how did this cell know how to divide and reproduce? What was the influence that sparked this all-important next step?

The good news is that these questions are easy to answer because cellular division goes through the exact same process as the emergence of the first cell. The only difference is that it takes place within a living cell, which gives the process a major boost. Plus, there is an inherent influence *inducing* reproduction to create a community of cells – the possibility of a community where the first cell can join with others like itself. This larger possibility acts as a vitalizing inspiration because it offers the possibility of *nested* all-for-one relationships with other cells. This describes the origin of the *first* species, which is a story that Darwin couldn't explain with his theory of evolution. All-for-one relationships offer a new solution to these origins.

Let's look closer at this process of reproduction. It begins with the possibility of giving birth to a new cell for the sake of something larger: to create a cellular community. It starts when enzymes step forward to lead the same exact process that gave birth to the first cell. However, in this case, the mother cell contributes its own enzymes and proteins to the process. The new host body forms inside the mother cell, offering it protection while the process takes place.

Since this happens *within* the strong all-for-one bond of the mother cell, the motivation for reproduction is much stronger. The leap is no longer nearly as big as the creation of the first cell. And all of the enzymes and proteins go through a process they already know. In both cases, the birth of a new cell from the mother cell happens only after the host body for the new cell is able to function on its own. Then, and only then, a new sentient agent that is waiting in the wings, in the quantum realm, is able to cross over to inhabit the body. Immediately after this, the cell divides because it is no longer one living cell but two, and they each need their own space to live their lives.

This is how the process of reproduction began and how it continues, according to this new theory of life. It is all motivated by a weak all-for-one relationship that forms a host body. This body can hold itself together inside the protective space of the mother cell for a limited time while it develops. It is then ready for a sentient agent to arrive and take over as leader of the body. Then it needs its own space to live as a sentient individual. This is the process of birth. And death is what happens when that sentient subject leaves the body.

Now let's move on from simple prokaryotic cells to the birth of multicellular creatures, including human beings.

10.3. Sexual Reproduction and the Birth of Animals

At the other end of the spectrum of organisms, something significantly different occurs through the sexual reproduction process of animals and human beings. There is a change that takes place before the first cell divides. A sperm cell penetrates an egg cell, transforming the egg cell into a zygote. This process begins with the fusion of two cells, the sperm and egg, into one, followed by the fusion of the two nuclei into one, to create a zygote.

Although this is called the moment of conception, no new cells emerge at this stage. In fact, the sperm cell gives up its life. Why would a sperm cell do this? For the same reason that we see slime-mold cells sacrificing their lives for the sake of the larger body that forms as the cells work together. This specialization is a trademark of all-for-one relationships. In this case, the sacrifice is not for the sake of the egg cell, but for the possibility of something much larger: a multicellular animal.

Sperm and egg cells in animals have no other function. This is why they are kept separate from other cells in an animal's body until it is time to try initiating conception. All other cells are dedicated to sustaining the flow of the animal's life. Sperm and egg cells are different. They exist to initiate the forming of a body for a new living creature. In other words, they are inspired by an all-for-one relationship that reaches beyond the mother's body from which they came.

This ability of the egg cell to transform, after conception, is something that only eukaryotic cells can do. Prokaryotic cells, such as bacteria, cannot transform; they only divide. This transformation changes the egg cell into a cell with a new genome combined from the genomes of the sperm and the egg. The new cell no longer has the same genetic map as the animal body from which the egg cell came.

This new genome ensures that the offspring will be different from its parents. Once again, we see here the drive for specialization. This gives creatures a stronger sense of individuality – a trademark that is crucial in the lives of animals, fish, birds, and even insects.

However, conception is simply the transformation of a cell. This cell, with its new genome, gives birth to new cells by dividing. The process of division is similar to the way prokaryotic cells reproduce. The new cell divides, creating a clone, then those two cells divide, creating four cells. We now see another change from single-celled organisms. Once a group of clone cells exist, they form a team that becomes the embryo of a developing animal. And, as soon as this happens, the cells start specializing and taking on specific roles to form the organs of the body. This is a sign that the group of cells have a weak all-for-one bond.

Each cell specializes when specific enzymes and proteins turn the key genes on and off through a process called "epigenetics." Each of the cells has the same new genome – they are all clones – but they are induced to specialize by catalysts regulating the process. As a result, some become lung cells, others become heart cells, brain cells, skin cells, etc. None of these organs can function fully until a contingent of cells has developed. All the organs then form a weak all-for-one organization as a group, led by a series of hormone catalysts that take turns as leaders. All the leaders pull the organs together, aligning their teams to all of the other organs to create the growing fetus.

The organs must all be functioning and working together as a cohesive, self-organizing group before a virtual agent can cross over to inhabit the body. This is when the animal gains its own sense of first-person perception and is then able to act as an individual. Once again, there is a clear reason why this moment of birth cannot happen sooner: The development of all the organs happens only through weak all-for-one relationships. All the work must be *done* by proteins and *led* by catalysts. Up to this point, virtual agents can only *influence* the course of events by offering the *inspiring possibility* of the body being inhabited and transformed into a *strong bond* that can live in a *larger world* with a *stronger flow of life*.

Here is some validation that this is right: When cells reproduce, they divide only after their organelles, including mitochondria, and genome are functioning and ready to go. Then, as soon as the virtual agent enters the new group, bringing its own first-person perception, the newly formed cell pushes its way out immediately. This happens simply because both cells need their own space to move and act as individuals with their own bodies.

The birth of creatures, such as reptiles and birds, occurs when they are ready to break out of an eggshell. The fertilized egg, laid by the mother, is filled with all of the nutrients needed for the weak all-for-one relationships, led by enzymes, to mature into a functioning body. The moment of birth takes place shortly before they break free of the shell because once it becomes an individual with its own first-person perception, it needs freedom from the constraints of the shell. This change takes place the moment a virtual agent inhabits the body.

Plants are also multicellular organisms. They begin theirs lives in a similar way, the moment they sprout. Seeds can remain dormant for years. Inside seed shells are cells and nutrients that need warmth and water to mature. Only after the seed body is ready for a new host, can a new sentient agent enter. Then, the plant sprouts and pushes itself out of its shell.

With mammals, the long process of developing a fetus takes place inside a mother's body. A few seconds after the transformation of a fetus into a living baby, the moment the new sentient being brings first-person perception into the new body, the mother feels the urge to push the baby out. This is a direct response to the baby's need to be free. As long as the fetus was nothing more than a collection of weak all-for-one processes, led by catalysts, the mother's body acted as a protective incubator and source of nourishment. However, as soon as a fetus becomes a baby with a life of its own, it needs space and freedom to act and live. The sentient subject then starts learning how to lead its new body.

I am going through this process, describing each step in detail, to show that this is the only way birth can work according to this new theory of life. The process must be guided and vitalized each step of the way by all-for-one relationships, just as the possibility of life was inspired by catalysts that lead teams of molecules to come together to create the body of the first cell. Birth occurs the moment a sentient agent inhabits a body that is ready and waiting.

If this theory is right, computers will never become conscious. They cannot take on a life of their own because they are not made of living cells waiting to be inhabited. How could a sentient agent inhabit a machine? It would need to form an all-for-one relationship with wires, batteries, and electronic chips that aren't sentient. How could a being form an intimate personal relationship with circuits that cannot respond intimately and personally? It is impossible.

Machines and computers, even quantum computers, are designed to be fully controlled by outsiders. Seeds, eggs, and fetuses develop specifically to originate actions from within as soon as they are inhabited by a sentient agent with first-person perception. These new insights into the processes of life offer us a clear and compelling story because of how well it ties all the pieces together in a way that makes sense.

Reproduction uses the same playbook as the origin of life, except, today, new life forms begin their lives as members of large communities. They step into an all-for one relationship with a living habitat that is responsive and inclusive. They enter an ecology filled with life that is waiting for relationships. Being born on such a planet offers a powerful boost to emerging new organisms. Life inspires life.

No secret plan hidden in DNA makes this happen. In fact, DNA developed long after the first communities of molecules began working together through catalysis. And most of the genes we see today probably developed after the first living cell. Genomes make it easier and faster to replicate the key proteins and enzymes needed to keep the flow of life going. This shows that genes serve a similar function as catalysis: speeding up and guiding reactions. DNA, however, is a product of strong molecular bonds, not the weak relationships we see with catalysts. This means that genes are not catalysts themselves. They are more like long-term memory, or perhaps recipes, created by the community to show future members how to make all the proteins and catalysts they will need.

Catalysts are the key to life, not just because they accelerate reactions by huge amounts, but because they lead and regulate the development of life. They guide the way forward, inspired by possibilities. This is a quantum process that is only possible through group relationships that work for something larger than themselves. This acts as a force that creates the nested heritage of life. It reaches all the way from quarks to protons and neutrons to atoms to molecules acting as catalysts to living cells to multicellular creatures, all the way to the ecology of our natural world.

Conclusions

Although still immature and not fully developed, this paper offers a scientific theory of life, including birth and death, that ties all the way back to quantum principles in a way that is fully consistent with quantum formalism.

It begins with one-on-one personal relationships. Then, after someone steps forward to lead a group, a weak all-for-one relationship emerges, creating a small break in the symmetry. This gives us the first signs of top-down causation. In rare and special cases, strong all-for-one relationships can emerge, creating a symmetry break that is clearly distinct between the “one” who is the leader and the “all” who form the group. These three types of *personal relationships* – one-on-one, weak all-for-one, and strong all-for-one – lead us to an explanation for what life is and how it works.

Complexity has long been seen as an important element in how life began. Now we can see that weak all-for-one relationships are at the center of this complexity. However, once we see how relationships work, it seems much simpler. It all comes down to this: whatever *can* happen has an influence on what *does* happen, when groups work for something larger than themselves.

It isn’t surprising that the importance of personal relationships has been missed by physicists and chemists. Studying life, however, shows how relationships alter the lives of organisms. As I said in Introduction to Part 1 of this ODQTL series (Marman, 2023a), the implications could be significant.

While the medical profession has advanced in countless ways over the last few centuries, especially in the treatment of disease, we can now see the possibilities for finding new ways of addressing *health*, through an understanding of how the flow of life works from the inside out.

It suggests that we are more than our body; we are the "one" in an all-for-*one* relationship that can lead and inspire our cells to work with us for the life we share with them.

We have a choice: We can be the kind of boss who doesn't care about our employees and takes for granted everything they do. Or we can express our appreciation by leading them into an inspired life with a higher purpose that increases the flow of life in all our cells. Try this yourself with a moment of contemplation. Can you feel the appreciation and thanks from your body?

Our close relationship with our cells erases the mind-body problem because mind and body seem separate only when we use third-person lenses. Mind seems to be the part of us that "thinks about" things when we act as an outside observer looking at the world. We watch our body objectively, seeing it only as meat, bones, and organs. We see no signs of mind or self.

This process of "thinking about" separates us from *our experiences*. Can we solve the mystery of life this way? Isn't the experience of life an important way to understand it? If we use a second-person lens, not a third-person lens, we find a solution to this riddle. Instead of "thinking about" things objectively, try "experiencing" the relationships that *involve you*. Can you see how your cells and organs are so close to you that you and your body act as *one*? Doesn't the split between mind and body disappear? Isn't it replaced by a personal relationship at the heart of life?

This means that Heisenberg (1958) was right when he said this:

> 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 was right because, as powerful as third-person lenses are for studying all forms of mechanical and chemical reactions, they are not enough to show us how to comprehend life itself. Our new theory shows why: We need lenses that can see the highly dynamic experiences shared by sentient beings in personal relationships that are hidden to outsiders. Can this explain why biologists hit a wall when trying to understand life? And can this resolve the same wall that blocked physicists from making sense of quantum mechanics?

During the Renaissance, a similar shift took place, when artists and engineers began learning from each other and from the philosophers of Ancient Greece. We see this clearly in the life of Leonardo da Vinci, (Isaacson, 2017, pp. 1-7) but many painters and sculptors of that time were inspired by the cross-pollination between engineering, art, and philosophy. Something similar happened in Ancient Greece. Pythagorus used mathematics to study musical scales and natural harmonies, radically changing their perceptions of both numbers and music. This led to a new appreciation of nature through math.

I see those times of inspiration and discovery as being shaped by larger possibilities. The promise of life draws us on to explore and understand. It calls us, like an invitation, to see deeper into nature with fresh eyes. The goal of the Renaissance and Ancient Greece was not to gain control over nature, but to learn by getting closer to the mystery at the heart of life. Artists and scientists joined together in those days to explore the unknown. This is an adventure that inspires us to be involved because the search changes us and opens new doors.

The idea that we come to inhabit our body from an invisible quantum realm seems foreign and strange to sciences that try to see everything through a third-person lens, but the idea is hardly new. Plato says that everything that happens originates from *soul* (Dombrowski, 2020, pp. 16-19). The idea that soul enters the body at the time of birth is also not new. Most of the old religious teachings from thousands of years ago taught the same thing. In the Old Testament of the Christian Bible, for example, it says numerous times that life begins with the first breath, and that soul exists before a person is born. (Lowrey, 2012)

On the other hand, our new theory challenges the more modern idea that human life begins with conception. It should be clear that any and all claims about *when* human life begins have absolutely no scientific foundation without first finding an explanation for what life is and how it works.

When Paul Davies described the significance of science accepting top-down causation and emergence as real processes (see p. 111), he predicted that it could impact theology as well. He appears to be right, since it challenges when life begins. Here is another example: The new theory of life proposed here says that there is no need for external designers of living organisms because the whole idea of external designers comes from the creation of machines. Davies predicted the same thing, that the idea of God as an external creator might be replaced by a God that inspires from above and calls life to evolve. In fact, all of Davies' predictions accurately described results from the theory of life in this series of papers. As he explained, the implications reach far and wide.

Once we find a lens that helps us see life, we can understand why organisms are so different from machines. Machines are, indeed, designed by creators to be fully controllable from the outside. If LoP theory is right, life does not work this way. It emerges when groups of sentient beings work together through all-for-one relationships, for goals larger than themselves.

Lately, as an attempt to overcome the limitations of reductionism, many philosophers and scientists have turned toward the idea of "wholeness" as the source of downward causation. In this case, wholeness is seen as something similar to the divine mind of God, as the source of everything. But, as we saw earlier, Davies could find no good example of how "whole-part causation" could work as a viable solution (see p. 109). He describes the problem this way: "How can wholes act causatively on parts if all interactions are local?"

I have come to see that it is not wholeness that gives us the inclusive experience that draws us on to become "one with life." It is the opposite: Our personal relationships with all of nature, in an inclusive way, lead to the experience of something larger than ourselves. This leaves us with a sense of wholeness. We are drawn to be involved in something larger than ourselves in a way that makes our lives more meaningful. It is inclusion with life and working with others that calls us, not wholeness. A sense of wholeness, nature, or even God, is the result because it is through relationships that we become involved in a larger, invisible reality.

However, whenever a new theory is introduced, it almost always raises more questions than it answers. In Part 1 (Marman 2023a) of this series and in this paper, Part 2, I have addressed what I see as the biggest biological and physical challenges for this theory. Each concern has led to a deeper understanding, offering new insights. We started with simple principles that seem only qualitative at first glance, but this leads to a detailed story of how life, birth, and death emerge from quantum relationships. This lays down a foundation that may be able to expand the emerging science of quantum biology far beyond the atomic level.

These two papers in the ODQTL series barely scratch the surface. After reaching this point in my research, I was left with many questions that led me to research and delineate the many challenges that this theory must overcome. Now, I feel confident that it is worth proposing the LoP principles as a way of opening doors to a scientific theory of life.

I have already begun preparing added papers to this series, to follow Part 1 and Part 2, to help provide a more complete picture, including:

1. When talking about simple catalysts and asking if a weak version of the strong force, called the nuclear force, is involved, it is still possible that these effects may be occurring in the atomic realm, where the nuclear force plays an important role. However, if the strong force is actively involved in group relationships between organisms, this requires a more radical proposal. This led me to ask if there is any evidence that might suggest the strong force is active far beyond the atomic-scale interactions. I have found two cases that provide fascinating possibilities because they display the same key characteristics of how the strong force, and only the strong force, works.

2. Philosophers have long been concerned about how consciousness fits into modern science. This leads to questions, such as, how consciousness emerges in our brain and how does it help us direct and control our body? Not satisfied with a lack of good answers to these questions, a new theory has arisen that asks if there is another solution: Is it possible that consciousness is fundamental and not something that emerges? This includes theories known as "panpsychism," which, in many cases propose the possibility that fundamental particles possess sentience. However, this leads to serious issues, known as "combination" problems, such as, how particles that are sentient can combine together to form cells and animals that possess sentience. It turns out that the principles proposed by LoP theory offer solutions that resolve these problems in new ways.

3. There are clear differences between the consciousness of human beings and animals, compared to insects, and an even bigger difference when compared to plants and single-celled organisms. Can we see incremental steps that progress from the signs of life we see at the quantum level to the simplest forms of life, all the way up to animals and people? Yes, there do appear to be notably clear steps in cognition.

4. As I said in the introduction, there is a fundamental problem at the core of Darwinian evolution that plays an important role in biology: It seems to act like a force and is often even referred to as "selection pressure," but it clearly does not act in present time or in a local place. It only acts across populations and lifetimes. This makes it sound more like a quantum force that is influencing the outcome. It turns out that when we look at cases where only *adaptation* to changes in an abiotic environment takes place, then the traditional way that biologists treat evolution holds up, but not when natural selection is used to explain *creative evolutionary progress*. This problem is well-known to biologists. However, once we see that quantum effects, such as entanglement and the

strong force are involved in relationships between organisms, then a new solution emerges. It is a solution that is consistent with the way Darwin himself proposed to explain true *progress*, solving a riddle that has bothered biologists and philosophers for over a hundred years.

5. If the theory of life proposed in this ODQTL series of papers is correct, then there should be clear signs that our health is directly affected by the all-for-one relationships we are involved with. There is evidence to support this prediction. This leads to a whole new way of understanding the meaning of *health*, not only in organisms, but in our families, organizations, and countries as well.

In all of the above cases, the new quantum theory of life passes the challenges, while revealing further insights into what life is and how it works. This is promising. However, this is just a start. For the LoP principles to stand, they need to apply to not just biology, but to physics, chemistry, sociology, and even psychology as well. Far more research is needed.

I also still have questions that I wonder about. For example, if catalysts actually act as leaders in weak all-for-one relationships, does this imply that they are sentient agents, or can a group of agents act as a catalyst? If a catalyst is inhabited by a sentient agent, does this mean that, when catalysts lead substrates through the transition of the reaction phase, a *virtual agent* crosses over from a quantum state to inhabit the molecular structure of the catalyst? In other words, could it temporarily become a case for a strong all-for-one bond, rather than a weak one? If so, does this always happen in all cases of catalysis, or just in special cases?

If this happens, it might explain why a catalyst remains unchanged through the highly volatile process of catalysis. Perhaps catalysts retain their individuality because they are momentarily inhabited by sentient agents.

The problem is that catalysis begins and ends as weak all-for-one relationships. We know this because all the substrates involved go their own ways before and after the reaction is over. This means that the catalyst might only leap into a strong all-for-one bond for just a few moments, and then return to being an ordinary molecule after its job as leader is finished. This sounds strange. Have biologists ever seen anything like this before?

It turns out that they have. Viruses act as if they are no more than strands of RNA until they get near a living cell. Then they spring into action. Many biologists claim that viruses are not alive because they show no signs of life on their own. But this leaves unanswered the question, *How can something that is not alive act purposefully to integrate itself into a living cell to replicate?* I wrote a paper, with evolutionary ecologist Alan Rayner (Marman and Rayner, (2016), that asks this question. The paper is called, *The Littlest Genome and the Question of Lif*e. These are the kinds of questions that continue to arise, showing that I have only scratched the surface.

What I find most promising about expanding the science of quantum biology is that it opens new doors for research and experimentation. Ultimately, that is one of the most important tests of a new theory: Can it help us find new ways to peer deeper into nature's hidden world? After all, isn't the call of nature, which pulls us on to explore her mysteries, the true heart of biology?

Addendum: Enzymes and Top-Down Causation

In section 9, I explored how catalysts appear to create a bridge from atoms to the emergence of cellular life by offering a new hypothesis: It is the strong force that drives enzymes and other catalysts to accelerate chemical reactions. This is different from the process of chemical reactions that flow downhill until they reach equilibrium with the environment because they are driven by the electromagnetic force.

The suggests that gathering and using energy is not enough to explain how life works. We also need to explain how organisms sustain themselves in a state that is far from equilibrium. Finding a theory that can resolve these problems is promising. However, what we need now is some experimental evidence to support this radical idea.

As I mentioned above (p. 101), Walker and Davies (2013) state that information flows in a unique way inside organisms: it uses top-down causation. In that same article, Walker and Davies (p. 6 and endnote 23) also describe a compelling case study that gives us a perfect way to test our new theory of catalysts. Let's take a look.

The authors of this case study, G. Auletta et al., (2008), start off with this introduction:

> Many scientists consider 'top-down causation' to be unreal – they believe it is just a complicated way of describing things which in the end confuses the real causal patterns, which are believed to be bottom-up only. It is also assumed that phenomena that are not easily understandable in a bottom-up way today will be well understood in the future. This approach has been extended to all natural systems thanks to the huge success of the application of reductionist methodology in physics and, in recent decades, in molecular biology and neuroscience. According to Francis Crick's famous dictum: 'You, your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behavior of a vast assembly of nerve cells and their associated molecules.' The emphasis in the phrase 'no more than' is a denial of the reality of anything additional to the pure assembly of cells and is therefore also a rejection of top-down causation....
>
> Nonetheless, there is a wide literature on the emergence of autonomous higher levels of complexity and the role of top-down causation in the hierarchy of complexity, expressing a need felt by many scholars to overcome traditional reductionism....
>
> In this paper, we try to refine relevant concepts in order to translate a philosophical examination of top-down causation into a scientific program able to make predictions and experimental tests. (pp. 1-2)

Auletta et al, then describe a recent experiment in which another team of biologists compared two types of bacteria. Each type uses a different RNase P enzyme in their cells. When these two RNase P enzymes were studied in test tubes, they found clear signs of structural and biochemical differences between the two enzymes that lead to distinctly different chemical reactions. The experimenters outlined four significant distinctions between the two enzymes that created different outcomes in their test tube experiments. (p. 3)

However, when these two enzymes are swapped with the cells they came from, both enzymes end up accomplishing the same functions. In other words, the enzymes can be interchanged from one type of cell to the other. It does not matter which bacteria cell they are in. Somehow each cell finds a way to use the two very different enzymes to achieve the cell's needs.

The results are surprising. If chemical reactions are defined only by molecular structures from the bottom-up, and enzymes are driven only by traditional chemical processes, why would both enzymes accomplish the results needed in different types of cells when they act so differently in test tube reactions? This appears to offer a compelling example of top-down causation because the enzymes appear to act in ways that are aimed at meeting the specific needs of the cell.

This fits perfectly with the theory presented in section 9, that catalysts act as leaders that pull molecules together to achieve a larger level possibility. Enzymes modify their shape and behavior dynamically to accomplish the needs of the organism. This is how, inside a living cell, catalysts work to continue the flow of life in that cell.

In other words, the behavior of these enzymes is led by the cell they happen to be in. This is why both enzymes can interchangeably accomplish distinctly different functions that are needed by different cells. The chemical properties of these two enzymes do not explain this behavior. However, this is how weak all-for-one relationships should work. The experiment provides evidence for the top-down influence of catalysis, validating our new theory of life.

However, while the original scientists who performed the experiment admitted that the results were "surprising," after they compared the chemical reactions of both enzymes closely, they did not come to the conclusion that this is a sign of top-down causation. They proposed a completely different explanation. They suggested that both types of enzymes were able to perform the same functions in different cells because those functions were "conserved" by natural selection:

> In the course of evolution, type A and B RNase P enzymes have developed RNA subunits with different architecture and individually tailored protein subunits, optimized for their specific cellular milieu. It is thus fascinating to observe that these RNase P enzymes still retain their biological function when their RNA subunit is exchanged with one representing a different architectural type. (Wegscheid et al., 2006, p. 416)

In other words, they are suggesting that natural selection created an original enzyme that served the needed functions. After thousands of years, the enzymes in these two different types of bacteria evolved as the bacteria changed in different ways, until both the cells and enzymes diverged significantly. However, their original functionality has apparently been retained.

The problem with this assertion is that it avoids the hardest part of the problem. It offers a sort of mythological story about the power of natural selection, as if this waves away the need to explain what we see happening before our eyes. In test tubes, these two enzymes behave differently from each other. The differences are remarkable. But, once these enzymes are inside living cells, they act interchangeably. How can a bottom-up process explain this?

How this evolved over thousands of years isn't the issue. This is happening right now. Why suggest that both enzymes retained the "biological function" needed from an ancestor enzyme? How does that help us explain why both enzymes can meet the needs of the cell, even though they are functionally different? This story falls far short of making sense of the surprising ways that living cells use catalysts to accomplish their needed goals. After seeing the results, the pressing question is: How do we explain what we see happening right now?

If we cannot explain what is happening before our eyes because the lenses we use are coloring our perceptions, then how are we going to solve the riddle of life?

Let me ask a different question: How do *molecules* gather energy and use that energy to keep cells alive? Should we suggest that they simply evolved to act this way? Does that, in any way, help us understand how life works?

Yes, cells have evolved to attain amazing abilities, such as reproduction, finding nutrition, and avoiding threats. But here is the hard problem we are facing now: We see enzymes that appear to be acting in goal-directed ways when inside living cells. How do they do that?

The story of natural selection is being used to distract us from how hard it is to understand life. We need to explain why two distinctly different enzymes that act in distinctly different ways when in test tubes, behave interchangeably in two different cells. These chemical reactions are acting in a startling way, as if the goal to be reached is influencing the outcome.

As we have seen, biological life is not possible without enzymes and catalysts. Our new theory proposes that the reason for this is that catalysis is driven by a different force than what drives all other chemical reactions. Catalysis is driven by the nuclear force, a weak version of the strong force, while all other chemical reactions are the result of electromagnetic forces.

It is electromagnetism that causes chemical reactions to flow downhill and release energy until they reach equilibrium with the environment. But the process of catalysis does not flow downhill. No electromagnetic energy is released through catalysis. We know this because the amount of energy released from chemical reactions is not altered by catalysts.

Further, enzymes actually *reduce* the entropy and chaos of chemical reactions by pulling molecules together to act as one, making the reactions happen billions of times faster with no added energy. No other chemical reactions act this way; they all *increase* entropy as they settle into equilibrium with the environment. The process of catalysis appears to be guided by *possibilities*, which is the same behavior we see at the quantum level. This appears to be a key to solving the mystery of how life works.

If all-for-one relationships explain this top-down behavior of catalysts, we should be able to find more cases like this. Auletta et al. make the same claim (pp. 1170-1171). They believe this offers a map for how to study enzymes to test for top-down causation. It also offers a way to further verify the new theory that it is catalysis itself that involves top-down influences. And, since catalysts are the key to explaining the origin of cells and the processes that keep cells living, this offers a compelling approach to further confirming our new quantum theory of life.

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

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