

1. Why ask if life is a grand illusion? If life is nothing but atoms obeying deterministic laws, then all the observable changes it produces, whether due to natural selection, biological agency, or human freedom, are only a grand illusion. But if the quantum domain allows the phenomenon of life to make a genuine difference to how things unfold, then the nature of reality may be stranger than deterministic physical theories would lead us to expect. In this essay I therefore ask: Is life's capacity to act on its own behalf real, or a mirage of underlying physics?

I will suggest that the view with the most explanatory power is to take appearances at face value: the phenomenon of life, via evolution, agency, and freedom, makes an irreducible difference to how reality unfolds. Life is not alone in this regard. I will refer to the general capacity of any complex physical phenomenon to impact how events unfold as *causality*, and the stance that accepts the reality of causality as *realism*. In the case of living beings, causality takes a distinctive form of expression that I call *agency*, which is the goal-directed ability to act on one's own behalf. In the case of human beings, first-person consciousness permits agency to become a source of *human freedom*.

This view has the advantage that it comes close to how most people intuitively understand reality. But this natural attitude came under severe pressure with the advent of classical mechanics and the spectacular successes of general relativity, which froze all of reality - past, present, and future - into one encompassing static block universe in which the various expressions of causality can be nothing but observer-relative illusions. While statistical mechanics made a big deal out of the ignorance arising from observer-relative uncertainty, it does not change the fundamental ontology of the physical universe.

Even with the rise of quantum theory, once heralded as freeing science from this strict determinism, it remains conceivable that agency and freedom are illusions. As I will show, deterministic interpretations of quantum mechanics retain the worldview of classical mechanics by suggesting that everything unfolds exactly as entailed by fundamental physical laws and the initial conditions of the universe. On this view, all forms of causality would again be reduced to nothing more than mere appearances based on the fixed trajectories of atoms pre-specified since the Big Bang.

But this determinism comes at the steep price of *anti-realism*: reality is turned into one grand illusion. To believe that causality is epiphenomenal, to treat the outcome of every act of life and mind as predetermined from the start of the universe, essentially amounts to emptying science of explanation: natural selection, agency, and human freedom become impotent shadows of initial conditions.

Daniel Dennett's concept of real patterns does not escape from this subversive implication: like seeing figures in the shifting clouds, we are essentially being asked to believe in regularities that could vanish without any deeper principle being violated. Worse, no alternative explanation of the underlying basis of this grand illusion is forthcoming. The probability that the Big Bang randomly encoded all of life's increasingly complex trajectories is so vanishingly small that, ironically, the ultimate price of determinism is to reduce the story of life to pure chance.

I argue that to move toward more productive scientific explanations, we must take life's appearance seriously: as matter endowed with real agency. If biological agency makes a genuine difference, then we need theories that can explain how.

Surprisingly, the search for such explanations leads us back to quantum mechanics, specifically, to stochastic interpretations that echo the principles of irruption theory, which was recently proposed as a realist framework for understanding life's agency and human freedom. In this way, a more accommodating starting point is secured: in a universe that is fundamentally quantum, life's causal powers are not necessarily an illusion.

I conclude by highlighting an intriguing self-similarity across these diverse domains of reality - physical causality, biological agency, and human freedom - which may hold clues to guide the search for how the quantum domain supports the domain of life.

2. Life appears agential - should we believe it? Natural selection clearly helps to explain life's evolution: organisms differ in their capacity to survive and reproduce; hence, some lineages adapt while others disappear. Biological agency also explains much of behavior, as organisms strive to maintain themselves in the pursuit of goals. Psychology applies this explanation to human beings, as beliefs and intentions shape individuals'

decisions. Human decisions are evidently consequential even at planetary scale, as our technological activity is altering climate patterns and is reorganizing energy flows, as is happening again now in the age of AI. Everywhere we look, life seems to be making a difference to the physical world, across a vast range of scales.

In his recent book *How Life Works* science writer Philipp Ball argues that this is no illusion but a remarkable property of matter itself: “The key to agency is that the agent itself acts as a genuine cause of change: agents act on their own behalf.” He acknowledges that skeptics worry about vitalism, but he insists that life leverages physical principles at all scales for its own benefit. If that is true, then agency must be understood in physical terms as well.

I am on board with Ball’s proposal, but I also see deep challenges lying in wait for us. The root problem is that, for this realist proposal about biological agency to be possible, the physical laws must allow enough causal slack for life to make itself. Classical mechanics and general relativity seemed to deny this possibility. But the quantum scale may open the door, depending on how it is interpreted.

3. The high cost of physical determinism Some interpretations of quantum mechanics remain resolutely deterministic. David Deutsch, in *The Fabric of Reality*, illustrates this worldview with a striking example: the trajectory of a single copper atom that ends up in a statue of Winston Churchill. He asks the reader to imagine that, at least in principle, one could predict this atom’s path from the Big Bang onward, including its role in the Second World War. The absurdity of this picture is clear: history itself dissolves into the predetermined dance of atoms.

Deutsch himself appeals to quantum interference as a real cause and uses this causality as evidence with which to argue in favor of the multiverse. More generally, his ambition is to support good scientific explanations by grounding them at their most appropriate scales, including explaining evolutionary adaptation and knowledge accumulation in terms of selection. But here too determinism takes its toll.

In the Everett interpretation, every branch of the multiverse and every interference pattern is already specified by the initial state of the universal wavefunction. The branches evolve deterministically according to the Schrodinger equation, and they are temporally aligned because they share the same time parameter. Hence, what may look to a copy of Deutsch in one of the branches of the multiverse like an outcome caused by a real interaction turns out to be merely epiphenomenal. If interference patterns were predetermined from the Big Bang, then quantum interference is ultimately no more genuinely causal than the classical interactions of atoms. In other words, even with the discovery of the quantum domain, it’s still possible to uphold the view that reality is just the playing out initial conditions.

Given that determinism drains the causality out of quantum interference, Deutsch’s main motivation to argue for the reality of the multiverse evaporates as well. Thus, if determinism is accepted at all, then arguably its more coherent form would be superdeterminism, as defended by theorists like Sabine Hossenfelder. On this interpretation, there is only one universe which deterministically evolves in such a way that all observable correlations merely point to their shared origin in the Big Bang.

Superdeterminism is consistent with the empirical record, yet it explicitly rules out physical causality, life’s agency, and human free will. For our purposes, this makes it less than compelling. Superdeterminism does not answer John Wheeler’s famous question of why the quantum. Moreover, it lacks a good explanation for why we observe all this complexity in the world, and it is forced to fall back on the assumption of an extremely specific, and hence extremely improbable, initial condition.

The challenge, then, is clear: can we do better than superdeterminism? Can we identify predictions that distinguish such a deterministic universe from one that exhibits genuine self-determination via real causality? That is the question we must now address.

4. If self-determination is real, how can we test it? It may be expected that the appropriate contrast to determinism is nondeterminism, but the shift to self-determination is deliberate. It is not enough to counter superdeterminism by highlighting that the quantum regime also permits nondeterministic interpretations. The aim is to go one step further and show that we gain explanatory power by taking life at face value. To do so, I will stick my neck out and point to ways in which the distinct ontologies that are implied by these interpretations of the quantum scale may be put to the test.

Deterministic interpretations (DI) of the quantum domain imply three core principles:

DI-1. Pre-formed change: Everything that happens was already specified by the initial conditions of the universal wave function. *DI-2. No privileged now:* The present has no special role in time's flow; it is just another point on a continuous trajectory of the wave function. *DI-3. Inconsequential history:* Because each state follows entirely from the one before, history cannot make a direct causal difference.

By contrast, if causality is real, the universe must satisfy conditions that are consistent with self-determination (SD) at the quantum scale:

SD-1. Spontaneous change: The present cannot be fully predetermined by the initial state of the universe or any other past state. *SD-2. Privileged now:* Each moment has to complete itself in real time from possibilities that were not fixed in advance. *SD-3. Historical contingency:* The present is directly shaped by history, including pathways opened by past spontaneous changes.

The simplest way to secure spontaneous change (SD-1) is stochasticity, which means that events can occur independently of all prior history. In a way, this stochasticity can be seen as a consequence of the privileged now (SD-2) in which self-determination takes place. For if the arising present slice in time is not yet determined in advance, it becomes impossible to eliminate all uncertainty about what will happen.

However, pure stochasticity cannot explain the organized complexity we observe because it severs the present moment not only from the Big Bang, but from everything since. A more plausible alternative is to couple the relative independence of the arising moment with historical contingency (SD-3). In other words, what happens now is not predetermined, but it is still conditioned by the specific pathways that the universe has already taken. Because each now moment must complete itself in real time from the available possibilities, all possible trajectories matter to what becomes actualized.

This gives us testable expectations: if reality is indeed exhibiting self-determination, we should find empirical signatures corresponding to spontaneous change, privileged now, and historical contingency at the quantum scale.

5. Quantum indeterminacy, reinterpreted Quantum theory was born out of surprise: its formalism was shaped by experiments that classical physics could not explain. From the perspective developed here, some of its exotic features - superposition, interference, entanglement, nonlocality, and collapse - can be reinterpreted as the expected signatures of a universe exhibiting processes that make a genuine difference to how things unfold.

We can already get a lot of mileage out of the standard nondeterministic interpretation developed by Bohr and Heisenberg. This so-called Copenhagen interpretation is consistent with principles SD-1 and SD-2 of a realist approach to self-determination. Importantly, the probabilities described by the wave function are treated as real and intrinsic to nature at the quantum scale. Moreover, measurement in the present moment makes a real difference to how the universe unfolds, and it does so in a way that is not completely predictable based on past states.

Support for SD-3 comes from nondeterministic interpretations that are non-Markovian, that is, which allow quantum processes to be dependent not only on the immediate past but on extended histories. Non-Markovian dependence can be imagined a bit like how cards that have already been played during a game have the consequence of changing the probabilities of the next card to be drawn.

An intriguing proposal in this regard is being developed by theorist Jacob Barandes, who has recently proposed a stochastic-quantum correspondence: a quantum system is an indivisible stochastic process evolving in configuration space under non-Markovian laws. Principle SD-2 may also provide an alternative perspective on Barandes' emphasis on the indivisibility of quantum processes, which essentially means that their probabilistic state transitions are intrinsically incomplete. For without determinism and in the presence of physical causality, each present moment is indeed incompletely specified, and it must assemble and complete itself from the available possibilities in real time.

6. From physical causality to biological agency The starting point for this essay was to take life's self-determination at face value. From this perspective, SD-2 is uncontroversial: biological agency can make

a difference in the present moment, when the future is still open.

Consistent with SD-3, it is also widely acknowledged that an agent’s ability to make a difference depends on its history: the accumulated pathways and achievements that shape what is possible now in terms of bodily capacities and environmental affordances.

As Sara Walker highlights in her recent book *Life As No One Knows It*, through extended evolution life is recursively amplifying the role of history until it becomes a defining feature of living matter. According to Walker’s *assembly theory*, the depth of historical contingency itself becomes a source of causal power, enabling life to convert counterfactuals into actual outcomes.

We may speculate that this empowering effect of historical contingency has a quantum basis. The quantum scale already permits non-Markovian processes, in which present outcomes directly depend on extended pasts. It would be fascinating if life has figured out a way to take advantage of this property to get around a Markovian causal bottleneck.

One way to understand Walker’s claim that the depth of historical contingency of life is part of what constitutes its causal powers is precisely in this way. Consider the following: To the extent that what life is doing now is also directly dependent on its past achievements, and given that those past achievements are partially a manifestation of past spontaneous change, life would become increasingly less dependent on the initial configuration of the universe. Conversely, over evolutionary timescales there could be a recursive amplification of self-determination, consistent with increasing complexity and agency.

This leads us to a clear testable expectation: to the extent that what current life does is based on historically empowered agency, then the consequences of this agency would deviate from the strict state-determined assumptions of Markovian processes. The precise mechanisms still need to be worked out, but this expectation aligns well with growing interest in non-Markovian quantum processes playing a role in biological systems. A prominent example is improved efficiency of energy transfer during photosynthesis.

Future work in quantum biology may want to consider examples more closely related to agency. Yet at the same time, we should not expect to find massive effects, since there is a shifting baseline of accumulated causality: we can only detect deviations from the assumptions of Markovian processes by comparing the current state to the immediately preceding state, which has already been historically amplified.

Consistent with SD-1, cognitive scientist Tom Froese’s has recently proposed *irruption theory* to operationalize the difference made by motivated activity in terms of a deviation from physiological inertia. According to this theory, the primary impact of an exertion of agential effort would be an irruption of spontaneous change, measurable in the form of a relative increase in structured noise.

Take the example of the brain: while neuroscientists can measure all the objective properties of brain matter, they cannot directly observe the intentional contents of mental states, and hence any consequences of those states will only appear indirectly as an unpredictable irruption into neural dynamics. The effect of an irruption is to liberate unfolding processes from fixed state trajectories.

Irruption theory makes a suitable complement to assembly theory. Irruptions ensure that a biological agent isn’t necessarily enslaved by its own history: stochastic decoupling from state trajectories creates a degree of freedom that is required to leverage that history to achieve goals in the present, a feat impossible in a deterministic Markovian world.

In this way, life exhibits clear signs of self-determination:

SD-1. Spontaneous change: Irruption theory posits that the difference made by agency manifests at underlying physical scales as spontaneous change - irruptions - that cannot be reduced to existing causal chains. This could be measured as agency-dependent relative increases in structured noise, such as fluctuations characterized by long-range temporal correlations.

SD-2. Privileged now: Agency can only make a difference in the present moment, when the future is still in formation. And there is a certain granularity to each now moment, lower bounded by the necessity for long-range integration. A classic example is the time required for the emergence of a neuronal cell assembly via large-scale neural synchrony.

SD-3. Historical contingency: Assembly theory posits that life's causal power grows with accumulated temporal depth. This suggests that life's use of quantum principles may show up as non-Markovian dependencies in biological systems.

Expanding this analysis to human freedom, we find intriguing correspondences that deserve future investigation. For example, there is the stochastic accumulator model of free will (SD-1), the specious present of inner time consciousness (SD-2), and enculturation and mind shaping (SD-3).

The nature of the physical interface between a goal-directed system and the quantum scale remains a central, outstanding question. Yet our analyses have revealed a new direction for exploring this issue. The abstract similarity across the domains of physical causality, biological agency, and human freedom may indicate that reality is organized in a self-similar structure: the quantum-matter relation is enfolded by a physics-biology relation, which in turn is enfolded by a biology-psychology relation. Recognizing this diversity of relations may improve the ability of science to carve nature at its joints.

7. Life is no illusion Nondeterministic interpretations of the quantum domain allow us to appreciate that the future is not prewritten, and biology shows us that history matters. Taken together, they reveal a universe where causality is not exhausted by the initial conditions, but can be recursively enriched by self-determination. Biological agency results from matter turning its historically accumulated causality into forward-looking, goal-directed action. Future work in quantum biology should explore how biological systems might be exploiting the existence of quantum non-Markovian processes to enhance agency.

To dismiss life as a grand illusion is to mistake determinism for good science. A better realism is possible: one that honors both physics and life by acknowledging that each moment is genuinely open, yet shaped by the pathways already taken. If so, then the story of life is not merely the shadow of an improbable configuration at the Big Bang. Life is the unfolding expression of a universe capable of making itself - from the quantum scale upwards - and thereby of allowing us to make a difference within it.