

When Light Becomes Life “What is life?”—Erwin Schrodinger Biology, they say, is chemistry with patience. Or perhaps it’s just misunderstood physics. For a long time, physics seemed to explain everything—from the motion of planets to the formation of molecules. Add time and randomness, and the rest would follow. Then someone asked the wrong question. In 1944, Erwin Schrodinger published *What is Life?*—a small book with a bold provocation: perhaps the fundamental processes of life could not be fully captured by classical physics. Perhaps there was something else—not supernatural, but subtle enough to slip through the known equations. Something physics, at the time, did not know how to name. It was easy then to ignore the provocation. But ignoring is not the same as answering. Decades later, biology began to display... strange behavior. Recent experiments reveal that certain living systems appear to use properties of quantum mechanics—such as superposition, coherence, and entanglement—in ways long deemed improbable, if not impossible, under classical models. And they do so in environments that, according to traditional physics, should destroy any trace of quantum coherence within microseconds: hot, wet, noisy. As if life had read the laws of thermodynamics—and decided to reinterpret them. Let’s begin with photosynthesis. In plants and bacteria, sunlight is captured by molecular structures and converted into energy with remarkable efficiency. In 2007, Engel and colleagues experimentally showed that this conversion does not follow a single rigid path: energy explores all possible routes simultaneously before collapsing into the most efficient one—a hallmark of quantum superposition. In enzymatic reactions, electrons and protons cross energy barriers without having the classical energy to do so—a phenomenon known as quantum tunneling, in which particles seem to bypass spatial constraints. In DNA, such fluctuations can alter base pairing and generate mutations—suggesting that even evolutionary “chance” may have quantum roots. Migratory birds seem to detect Earth’s magnetic field with a precision that defies conventional explanations. A plausible hypothesis is that quantum reactions in cryptochromes—light-sensitive proteins—enable this orientation via entangled radical pairs. As for smell, studies propose that beyond the shape of odorant molecules, the olfactory system may also detect specific vibrational frequencies—as if we “heard” scents through phonon-assisted electron tunneling. The point here is not to romanticize life as mystical. It is to recognize that certain biological phenomena, based on what we know, seem to exploit aspects of quantum physics functionally. For now, quantum biology is an emerging field—more descriptive than explanatory. It is not yet a unified theory, but a growing collection of anomalies—cases where biological behavior appears to rely on quantum rather than purely classical principles. What once looked like irrelevant noise is starting to look like meaningful signal. Perhaps the task is not merely to discover new mechanisms. Perhaps we must revisit the very definition of life: not as a mere sum of molecules, but as a coherent system sensitive to informational patterns that oscillate between the predictable and the improbable. Life does not simply tolerate noise—it negotiates with it. It organizes itself at the edge of instability. It uses chaos as a resource. It is too early to say where this will lead. Quantum biology is still taking shape. But it reopens, in a new light, Schrodinger’s original question: Perhaps the question is not only what life is—but where it begins to be.

From Photosynthesis to Human Bioenergetics: Coherence as an Organizing Principle What makes life work is not just energy—it’s the way energy flows. Matter alone does not explain biological complexity. Life is not merely made of atoms; it makes them dance in coordinated rhythms shaped by principles that do not always fit the expectations of classical biochemistry. After Greg Engel and his team (2007) showed that energy transfer in photosynthesis proceeds through quantum coherence, Martin Plenio and Susana Huelga proposed, in 2008, something even more provocative: thermal noise—traditionally cast as the enemy of coherence—can, in certain contexts, support it. The mechanism, known as dephasing-assisted transport, suggests that disorder can guide rather than hinder. This is not confined to leaves. Human cells appear to do something analogous. Mitochondria—evolutionary descendants of ancient photosynthetic organisms—are responsible for cellular energy production. So far, nothing new. What stands out is that these organelles seem to respond to light, especially in the near-infrared range (600-1000 nm). When exposed to this spectrum, they produce more ATP, reduce reactive oxygen species, and show improved biochemical performance. This phenomenon is called photobiomodulation. While part of its effects can be explained by conventional photophysical mechanisms, there are indications that light reorganizes internal electromagnetic fields, restoring functional coherence. In other words, light doesn’t just activate—it structures. And if light goes in, it also comes out. Since the 1990s, it has been known that living systems spontaneously emit photons at extremely low intensities; this emission became known as “biophotons” (a term popularized by Fritz-Albert Popp). More intriguing than the mere fact of emission is its possible organization: it is an ultra-weak emission

that may be organized—suggesting an informational role—although the demonstration of optical coherence in living tissues remains under investigation. Later, Bokkon (2010) proposed that mitochondria are the main source of this emission in brain cells. Furthermore, Tang and Dai (2014) observed that emission increases with synaptic activity, indicating a possible functional role in neural communication. The hypothesis then becomes bolder: mitochondria could function as biophotonic antennas, capable of emitting and absorbing light in functional patterns. Some authors have proposed that health may reflect the maintenance of a coherent photonic milieu across scales, whereas pathology could involve its disruption. At present, this remains a working hypothesis requiring rigorous testing in humans (Mould et al., 2024). What emerges is the suggestion of a bioenergetic continuum spanning life forms—from chlorophyll to cortex—articulated by structures that operate with and through light. A functional axis that is not metaphorical but biophysical. In this sense, life not only tolerates light. It uses it with precision—and, by all indications, also produces it for purposes not yet fully understood. If quantum coherence shows up in living systems where it supposedly shouldn’t; if light organizes mitochondrial function; if biophotons participate in neural activity—then perhaps it is time to reexamine some core assumptions. Living organisms may be less like adaptive machines and more like resonant systems—sensitive to frequencies, rhythms, and phases. Or perhaps not. But if mitochondria are listening to light and responding with coherence, perhaps we should start listening to what they have to say.

Biophotons and the Language of the Cell Cells communicate—of that there is no doubt. The question is: how? The traditional answer points to chemical messengers—neurotransmitters, hormones, cytokines—that orchestrate reactions. But is that enough? Consider this: the body houses trillions of cells performing billions of reactions per second in functional synchrony. It is hard to reconcile such harmony with slow chemical signals in a viscous, noisy medium. Something seems to be missing—or perhaps we are listening on the wrong frequency. The hypothesis advanced by Fritz-Albert Popp (1994)—that ultra-weak photon emissions from living systems could exhibit some degree of optical coherence, functioning more like signal than noise—was, and remains, provocative. Building on it, other researchers (Bokkon, 2010; Tang & Dai, 2014) probed whether light is merely a metabolic byproduct or a functional component of cellular communication. Theoretical and experimental work reports that emission can increase with cellular/neural activity and modulate with physiological state, including conditions of stress and cell death. Even so, a definitive demonstration of optical coherence in living tissues—and its functional role—remains under investigation. Emitting light, however, does not by itself imply communication. Language requires tuning. Here physics helps. Strogatz (2003) showed that systems composed of coupled oscillators—units that vibrate independently yet influence one another—tend to synchronize spontaneously, even under external noise. This happens with clocks, fireflies, and heart cells. Perhaps with cells as well. Decades earlier, Frohlich (1968) theorized that living systems could sustain coherent vibrational modes far from thermal equilibrium. Cellular structures would act as nonlinear oscillators, powered by metabolic energy, capable of storing and transmitting information without relying solely on physical molecules as carriers. Transposed to biology, the model suggests that cells might function as electromagnetic emitters and receivers, using coherent photons as signals. Light would cease to be mere biochemical noise and become part of the informational infrastructure. If confirmed, this would position light as part of the cell’s informational infrastructure; however, direct demonstrations of tissue-level optical coherence and its physiological role remain under investigation (Mould et al., 2024). In this scenario, living tissues become resonant networks—coherent systems of light emission and reception. Cellular communication would gain speed, simultaneity, and non-locality. A silent optical internet. None of this is established, but neither has it been refuted. Evidence exists, and the models are internally consistent. If confirmed, the implications could reshape our view of the human body—from a biochemical machine to a complex photonic system. If true, biophotons may have been life’s first language—preceding synapses, perhaps even membranes. Light as medium. Light as signal. Light as a rudimentary self-awareness. Perhaps the cell says more than we hear. Perhaps it is speaking all the time. And maybe, by learning to listen—in photons—we will discover that life, before it spoke in molecules, was already whispering in light.

Mitochondria, Consciousness, and the Thermodynamics of Coherence Consciousness remains one of biology’s greatest enigmas. Despite advances in neural mapping and correlations between brain patterns and mental states, we still lack an answer to why certain chemical reactions give rise to subjective feeling. This is the “hard problem of consciousness.” Perhaps the mistake lies in our focus. Reducing the brain to electrochemical circuits is useful for therapies, but it may be insufficient to explain first-person experience.

Consciousness may depend on properties not yet formalized within biology. As noted earlier, living systems can sustain coherent electromagnetic oscillations—especially in membranes and proteins—maintained by a continuous flow of energy, forming coherent, self-regulating systems. In this view, the brain would be more than a symbolic network: it would be a multiscale oscillatory field. Rhythms such as alpha, beta, and gamma would not be mere noise, but expressions of structural harmony. This is where mitochondria come in. Beyond producing ATP, they regulate calcium, control reactive oxygen species, and emit light—biophotons. This faint light may help integrate cellular functions. Some hypotheses suggest that it couples internal structures such as microtubules, ion channels, and even DNA. This idea approaches the Orch-OR theory (Penrose & Hameroff, 2014), in which consciousness would emerge from orchestrated quantum collapses in microtubules. The model is controversial, chiefly because it requires quantum coherence in the noisy cellular milieu. As an alternative, the mitochondrial-biophotonic model proposes that consciousness emerges from the interaction between biophotons and coherent electromagnetic fields synchronized with neural networks. Here, light is not a byproduct but a functional integrator. Another approach, such as McFadden’s (2002) electromagnetic field theory, places conscious experience in brain-generated EM fields arising from synchronized neuronal firing. Although more readily measurable, it still does not explain why such fields would be conscious. If the mitochondrial model holds, consciousness could be understood as an emergent property of cellular electroluminescent coherence. Disruptions to this field—through inflammation, mitochondrial dysfunction, or synaptic collapse—might help explain states such as coma or dissociation. The converse may also be true: practices that increase coherence—such as meditation and rhythmic breathing—may support mental integrity. Not through mysticism, but through physiology. Perhaps the “self” does not reside between synapses, but in the zones of resonance between fields. Perhaps it pulses—quite literally—in the light.

The Challenge of Decoherence: How Life Sustains the Quantum Quantum physics demands isolation. States such as superposition and entanglement are fragile: a small thermal or vibrational disturbance is enough to collapse them. That is why it is surprising when quantum effects are observed in living systems, especially in warm, noisy cellular environments—the very places where coherence should vanish. In photosynthesis, light energy is transferred by coherent superposition even at room temperature. In the cryptochromes of migratory birds, radical pairs seem to maintain entanglement long enough to guide flight. In enzymes, electrons and protons cross energy barriers by tunneling. The question shifts: it is no longer whether life uses quantum effects, but how it makes them viable. One hypothesis posits highly organized intracellular microenvironments—with hydrophobic pockets and low thermal turbulence—that could sustain quantum coherence for functionally relevant periods. More than that: in certain contexts, noise can help. The dephasing-assisted transport model of Plenio and Huelga (2008) suggests that thermal noise can stabilize quantum phases, promoting efficient energy transfer. In addition, cells generate intense electric fields—on the order of 10^7 V/m—that organize ionic flows and local architecture. At the center of this system may be water—not ordinary water, but “structured water.” Del Giudice and collaborators (1985) proposed that it can form resonant patterns capable of sustaining coherent states. From this convergence emerges a biology that is neither purely classical nor purely quantum: a liminal, adaptive regime that integrates noise into its very functionality. Perhaps consciousness is the pinnacle of such coherence—a form of organization that survives chaos and knows itself while it lasts. Perhaps thought—this very one—is simply one of those patterns trying to persist.

The Light That Thinks – Proposed Experimental Protocol Making hypotheses is easy; putting them to the test is where science begins. Quantum biology already has an alphabet—cellular photons, coherence, electromagnetic fields—but elegant theory is not enough: we need clear procedures, reliable measurements, and the courage to be wrong. The hypothesis is simple and bold: near-infrared light can reorganize the brain’s mitochondrial energy economy, and this may be reflected in more coherent neural activity linked to conscious experience. This is not a metaphor; it’s feasible today. We propose an integrated, reproducible, and informative protocol: 1. **Controlled light perturbation.** We apply gentle near-infrared light (clinical range) over the prefrontal cortex, a region associated with attention and metacognition. Half of the sessions are sham to preserve double-blinding. 2. **Two readout windows.** Before and after light, we record: High-density EEG to track oscillations and synchrony across regions (Shahdadian et al., 2024). And broadband optical spectroscopy over the frontal region (forehead) to follow, in real time, changes in cytochrome-c-oxidase (oxCCO)—a key enzyme in energy production—used here as a metabolic marker (not “coherence” in the strict sense). In humans, oxCCO increases after tPBM tend to be acute (on the order of minutes), and

the persistence of late effects remains under investigation (Wang et al., 2017). **3. Listening to the body’s own light.** In two intervals of total darkness, a photomultiplier tube (PMT) measures ultra-weak photon emission from the head—an approach already applied in humans and even correlated with EEG changes during visual imagery tasks. Our goal is exploratory: to test whether this biological light changes after the intervention and whether it covaries with what we observe in EEG and metabolism, following established detection methods and precautions (Kobayashi et al., 2009).

What do we expect? A boost in prefrontal mitochondrial metabolism, more coordinated brain rhythms, and a statistical link between energy and information. Photon emission may oscillate in tandem, suggesting that the brain not only consumes light—it may also organize with it. **Controls and cautions.** The study is crossover, double-blind, and uses safe light parameters. We eliminate any stray light during dark blocks, synchronize equipment, and pre-register analyses. Even so, we remain cautious: the optical measure is a proxy for metabolism; photon detection is subtle; and correlation is not causation. **Why it matters.** If confirmed, this design brings cognition, metabolism, and light together as facets of a single process—a kind of neurophotobiology. It opens space for optical interventions in mitochondrial dysfunction, light-based adjuncts for treatment-resistant depression, and technical support for integrative practices—not as mysticism, but as engineering of the living. We are said to be made of stardust, perhaps also of starlight. If consciousness is, in part, a phenomenon of coherence—vibrational, electromagnetic, photonic—then studying the mind by what it emits may be method, not fancy. And perhaps we will not find an immobile center of mind, but a field: a form that persists when light, for an instant, finds stability.

A New Light on Life “What is life?”—Schrodinger asked, like someone crossing a forest guided only by a spark of intuition. What he found, in the end, was not a final answer but a trail—a thread of coherence, a persistent improbability, an order that resists collapse. A physical enigma at the heart of biology. This essay followed that trail. We watched photons traverse photosynthetic networks with improbable precision. Tunnels through which protons slip past energy barriers. Enzymes that oscillate. Light emitted by mitochondria—small bioenergetic power plants that may be more organized than we assumed. And behind it all, a recurring pattern: functional coherence amid noise. Here, however, coherence is not a metaphor—it is an operational condition. A property of far-from-equilibrium systems that maintain their integrity by integrating instability. Systems that cultivate order from within. We saw that photosynthesis operates like a quantum network. That the brain exhibits rhythms that couple into meaningful patterns. That the cell, beyond biochemistry, behaves like a subtle electromagnetic system, capable of emitting and modulating light. None of this denies molecular biology. It widens its frame. It suggests that, alongside molecules and mechanisms, we may need to consider frequencies, fields, and coherence as constitutive dimensions of living architecture. In this context, quantum biology does not seek to replace the current paradigm but to sharpen its resolution: to reintroduce life as a phenomenon of tuning, not merely of structure; to integrate energy, information, and form as expressions of a single dynamic system. On this new map, light is not a spiritual metaphor—it is an organizing variable. And noise—once the villain of precision—becomes a subtle partner, capable of synchronizing, amplifying, and revealing the unexpected. In this view, the cell ceases to be an isolated functional unit. It becomes a point of intersection between form and vibration—a place where rhythms and structures meet, where biology draws closer to physics without losing its identity. And consciousness? Perhaps it is not a mere byproduct of complexity, but a refined expression of systemic coherence—a field that organizes itself and, in doing so, becomes aware. A functional reflection—one that also feels. This hypothesis can—and should—be tested. We can measure biophotons, map patterns of coherence, apply optical stimuli, and observe the effects. What may be lacking is not technology, but the willingness to look through wider lenses. We are in transition: from a biology of substance to one of relation; from a science of structure to a science of tuning. A shift that does not erase what came before—it inscribes it within a broader field. Schrodinger’s question does not end with answers. It persists through attention—through the willingness to see that life, before it reacts, responds. And that what we call light may not only illuminate reality—but organize it. Proposals linking coherent photonic organization to health are intriguing but preliminary, and will require systematic human studies before firm conclusions can be drawn. Perhaps the greatest legacy of quantum biology will not be to discover new mechanisms, but to propose a new way of seeing. What we offer here is not a complete map. It is a sketch. Of an organism that not only functions but communicates. Of a cell that not only metabolizes but emits. Of a mind that may not be contained in the brain—but in the coherent pattern that emerges when everything is in phase. And if anything remains at the end of this path,

it may not be certainty. But enough to keep us investigating. As long as the light lasts.