

Abstract

This essay explores the potential relationship between biophotons and epigenetics, proposing the idea of a quantum layer in DNA communication. It begins by presenting how epigenetic modifications enable life experiences and environmental factors to influence and transmit individual traits across generations. Simultaneously, the essay examines the phenomenon of biophotons, ultra-weak photons emitted by living systems whose biological role remains uncertain. The central hypothesis is that these photons may carry information and link stress-induced photon emission with epigenetic changes that persist over time. Drawing inspiration from the revolution of quantum communication through photons, the essay explores the possibility that nature may already employ a similar method to encode, transmit, and preserve information beyond the genetic code. Though speculative, this idea opens a space where biology and quantum physics converge, suggesting that a hidden photonic dialogue may sustain and shape the evolution of life.

1. Introduction

Quantum mechanics, perhaps together with the theory of relativity, is the theory that has most changed human beings' conception of the world around them. Its implications and experimental confirmations have led to the acceptance of the idea that "the smallest units of matter are not physical objects in the ordinary sense" (W. Heisenberg), or at least, the behavior of the microscopic world is significantly different from the macroscopic one. Many physical processes observable in the world around us are linked to quantum mechanics, and even life on our planet is possible thanks to quantum effects. For example, the Sun, despite its immense heat, is theoretically too 'cold' for nuclear fusion to occur according to nuclear physics. Thanks to quantum tunneling, however, hydrogen nuclei can actually fuse, and life on Earth becomes possible thanks to the source of energy given by those reactions. We can also say that many quantum phenomena have enabled and continue to enable life on Earth. For example, the harmful ultraviolet radiation from the Sun is absorbed and scattered by atmospheric molecules through quantum transitions, while high-energy cosmic rays are shielded by interactions ultimately rooted in quantum processes. Without such effects, life on the planet's surface would hardly be possible. Although these processes are essential for life to flourish on our planet, it is clear that, for now, we are only beginning to glimpse the possible quantum signatures hidden within biological systems. These signatures are to be found in the still poorly understood processes that underlie life, existence, and the survival of species.

Since the discoveries about the microscopic world brought about by quantum mechanics were confirmed by experiments, a great technological revolution has been underway. In the coming decades, this drive will focus on quantum technologies such as communication, computation, and sensing. Quantum information is one of the areas in which global research is most focused, and where the quantum revolution predicted for the next decades will have the greatest impact. Entanglement has been widely theorized as a resource for secure communication protocols such as quantum key distribution or teleportation, and technology is approaching the point where such protocols become practical reality. It is for this reason that a possible connection between life and quantum mechanics should be sought in the way our bodies communicate. If quantum mechanics has already reshaped how we foresee future communication, should it also play a role in how living systems exchange information?

In exploring possible answers to this question, we must necessarily delve into the complex world of biology and focus on what could be the still poorly studied signals that the molecules in our body exchange, and above all, where they originate from. To search for such signals, one must look beyond classical genetics. Epigenetics, the study of how information is written and transmitted outside the DNA sequence, offers a fascinating entry point to investigate whether life encodes and communicates in ways that might even touch the quantum realm.

2. Epigenetics

2.1 Classical Epigenetics and Transgenerational Epigenetic Inheritance

Epigenetics is the study of heritable changes in gene expression that do not involve alterations to the DNA sequence itself. The term was first coined in the 1940s by Conrad Waddington, who envisioned a framework to explain how genes interact with the environment to produce observable traits. Research in this field aims to understand how habits and environmental factors, such as diet, stress, and even experiences, can alter gene function without rewriting the genetic code. These reversible changes, often mediated by mechanisms such as DNA methylation, histone modification, or non-coding RNAs, act like chemical “switches” or “markers” that regulate DNA accessibility and turn genes on or off. At the macroscopic level, this regulation can shape traits, behaviors, and even instincts. In this way, epigenetics provides a molecular bridge between the environment and the genome, opening the possibility that life experiences can influence not only individuals but also their descendants.

A very interesting field of epigenetics is “Transgenerational Epigenetic Inheritance” (TEI), which explores the transmission of these epigenetic modifications not only to daughter cells, but also to progeny across multiple generations. Normally, during the formation of reproductive cells and in the early stages of embryonic development, most epigenetic modifications are reset through a process called “epigenetic reprogramming”. However, some marks manage to escape this reset and are passed on, effectively carrying a form of biological memory from one generation to the next. From this perspective, epigenetics is not only responsible for certain responses of our bodies to external stimuli, but also plays a role in transmitting adaptive responses to offspring. In doing so, it can pass on survival instincts and information across generations, potentially influencing the course of a species evolution, a fundamental building block for life and for our own existence.

TEI has been well documented in plants, especially under stressful conditions. Although linking traits directly to epigenetics is more challenging in animals, evidence exists in specific cases. One influential experiment that highlights the importance of transgenerational epigenetic inheritance for animal survival was conducted by Dias and Ressler (2013) using a mouse model. In their study, Dias and Ressler demonstrated that parental olfactory experience influences behavior and neural structure in subsequent generations. The researchers exposed adult male mice to the synthetic odor acetophenone, which has no natural biological relevance, and paired it with mild electric shocks. After several pairings, the mice learned to associate the odor with the aversive stimulus and developed a strong fear response to acetophenone alone. Findings related to TEI emerged when their offspring, as well as the third generation, which had never been exposed to the shocks, exhibited increased sensitivity and fear responses to acetophenone. Further analysis revealed that this transgenerational effect was linked to changes in the nervous system and germline. The olfactory receptor gene responsible for detecting acetophenone showed altered DNA methylation patterns in sperm cells, and the offspring had an increased number of sensory neurons that were responsive to the odor. These results suggest that the parents’ learned experience was transmitted epigenetically to subsequent generations, effectively encoding a survival-relevant response into the lineage. This experiment is significant in suggesting that some traits and instincts may arise from the accumulated experiences of our ancestors, transmitted through epigenetic mechanisms as a way of preserving the species.

Studies conducted after the Dutch famine of 1944-1945, as an example, provide evidence for a similar process in humans. These studies showed that prenatal exposure to extreme malnutrition left epigenetic marks that affected the health and development of subsequent generations. During that time, the Nazi blockade caused severe food shortages for much of the population. Researchers later examined children who were in utero during this period and found that exposure to extreme malnutrition in the womb was associated with long-term health consequences. Compared to their siblings who had not been exposed, these individuals showed higher rates of obesity, cardiovascular disease, type 2 diabetes, and mental health disorders. Strikingly, the effects did not end with the generation that was directly exposed. Follow-up studies suggested that the grandchildren of women who were pregnant during the famine displayed similar health outcomes, supporting the idea that epigenetic modifications were transmitted across generations. The Dutch famine thus left a scar not only in history, but also in biology, illustrating how environmental stressors can leave a lasting imprint across generations.

After reviewing what epigenetics is and how it contributes to the life and the survival of individuals and species, one question arises: How does a sensation or stress signal perceived by the nervous system transmit

information to the body, ultimately determining which genes are active in our DNA? Biology offers several explanations for how our feelings can affect our DNA. Stress, fear, and other intense experiences trigger hormones that travel throughout the body, influencing which genes are active, molecules act as messengers, carrying signals between organs and sometimes reaching cells that will form the next generation and even food we eat also contributes because nutrients provide the “chemical tags” that help switch genes on or off. These classical mechanisms demonstrate a clear link between the environment and our biology. However, they do not fully explain how highly specific responses, such as the memory of a dangerous odor or the biological effects of famine, can be encoded in our genes and then be transmitted to future generations. If traditional biology cannot fully explain how experience becomes hereditary, perhaps the answer lies in more subtle, hidden processes.

2.2 Epigenetics and Quantum Mechanics

In light of this evidence, epigenetics not only has the peculiarities to be the “Biology’s Quantum Mechanics” (R. A. Jorgensen), but it could be the real building block of life in which quantum mechanics plays a fundamental role. Some researchers have begun to speculate that quantum phenomena may subtly influence the way epigenetic regulation works. A recent proposal describes the existence of a “quantum physics layer” of epigenetics, in which processes like charge transfer along DNA bases could be supported by quantum tunneling. Another intriguing idea comes from the so-called spin selectivity of DNA, where the helical, chiral structure of the molecule could favor certain electronic spins over others, influencing how proteins and chemical modifiers interact with the genome. While these effects remain theoretical, studies have shown that such quantum behaviors can persist under conditions close to those of living cells, suggesting that they might indeed play a role in biology. Recent modeling work has even suggested that quantum charge transport could survive the noisy environment of the cell long enough to influence epigenetic regulation. The fascinating hypothesis I propose, linking epigenetics to quantum processes, is finally based on a physical process that is attracting increasing interest from the scientific and physics communities: the emission of ultra-weak photons by living tissues, more commonly known as biophotons. After reviewing the recent findings on biophotons, the possibility that a dialogue of photons could be at the basis of epigenetic changes will be explored.

3. Biophotons

3.1 Biophotons Evidences

Biophotons are a relatively new frontier linking biology and physics. The first evidence dates back to the work of Fritz-Albert Popp in the 1970s, when the two scientists demonstrated that all living cells spontaneously emit ultra-weak light, now known as Ultra-Weak Photon Emission (UPE). Since then, numerous studies on plant and animal organisms have supported the hypothesis that this emission is a universal phenomenon, potentially linked to metabolic processes and, remarkably, intracellular communication. For example, germinating seeds, such as wheat and cucumber seeds, have been shown to emit photons continuously throughout their development. This indicates that light production is closely linked to growth and metabolic activity. Later research extended these observations to animals. Ultra-weak photon emission was detected in the brains, livers, and muscles of rodents under normal physiological conditions. Each tissue exhibited a characteristic emission profile. More recently, it has been demonstrated that humans also emit biophotons, which can be measured using highly sensitive photomultiplier systems. These experiments recorded ultra-weak light from the skin and even the eyes, reinforcing the idea that biophoton emission is a fundamental, universal property of living matter. While studies on biophotons are intensifying and their existence has been firmly established, the scientific community still does not understand the underlying reason for their generation. Their biological role remains uncertain. The central question is whether UPE is merely a byproduct of cellular biochemical reactions or if it plays a functional role in the body, serving as a marker or mediator of processes not yet fully understood. One of the hypotheses could be that biophotons are involved in intracellular communication and epigenetic signaling: if future human technologies will rely on (entangled) photons for communication, it is reasonable to ask whether nature has already adopted a mechanism also involving photons as part of life’s communication strategies.

3.2 Biophotons Emission and Stress Responses

A well-established feature of biophoton emission is that it is not static but is strongly influenced by environmental factors and the stress experienced by living tissues. Studies on plants, such as sunflowers and wheat, have shown that exposure to stress, such as parasite infestation in sunflowers, leads to an increase in UPE. These findings suggest that cells respond to environmental challenges with light signals and even open the possibility of using biophoton emission as a noninvasive method to monitor the health and vitality of crop plants. Many experiments have revealed a correlation between stress, disease, and temporary increases in biophoton production, even in animals. For example, studies have shown that metabolic or pathological stress in rodents can trigger measurable increases in ultra-weak photon emission. One intriguing study observed an increase in biophoton production during the metamorphosis of certain beetles. This suggests that significant physiological changes in insects are accompanied by a corresponding rise in biophoton emission. These findings support the notion that UPE could serve as a sensitive indicator of physiological and metabolic states in various animal species. Studies on biophoton emission also in humans have provided compelling evidence that UPE is measurable and responsive to physiological and environmental conditions. Early investigations focused on the skin and demonstrated that it emits ultra-weak light with distinct temporal rhythms and lateral asymmetries reflecting underlying biological cycles. Subsequent studies have shown that this emission increases in response to external stressors, such as exposure to ultraviolet or visible light. This suggests that UPE may act as a sensitive marker of oxidative stress and other cellular processes. More recently, researchers have explored the brain as a source of UPE and revealed that photon emission from neural tissue can be detected noninvasively and may correlate with mental activity and cognitive processes. Together, these results suggest the intriguing possibility that biophotons may participate in cellular communication by transmitting information within and between tissues in a manner that complements classical biochemical signaling. If the light emitted by human cells reflects their physiological states and responses, then it could represent a highly organized mechanism through which cells coordinate their functions and adaptively respond to environmental stimuli.

4. Biophotons and Epigenetics Modification

4.1 The Biophotonic Trigger Hypothesis: A Possible Mechanism for Epigenetic Signaling

An interesting peculiarity of biophotons has been observed in recent studies: in addition to skin and neurons, one of the most active sources of biophotons in the human body has been found to be DNA. This observation was made by Pietruszka and Marzec has opened up many hypotheses. The one presented in this essay is that biophotons are themselves products of the transmission of information between DNA molecules. This important finding paves the way for the search of a link between biophotons and epigenetics.

One possible speculation in this regard is that biophotons may serve as signaling elements within living organisms, allowing cells or molecules to transmit subtle messages that coordinate biological responses. This perspective could help explain the observed increase in UPE during stress or during profound physiological changes such as insect metamorphosis. These faint photonic signals might not act as carriers of energy, but rather as triggers, initiating or modulating the chemical cascades underlying the body's adaptive responses to external or internal stimuli. The link to epigenetics naturally follows. Information conveyed through biophotons could represent a layer of communication that influences chromatin structure and gene regulation. Given the experimentally demonstrated emission of UPE from DNA, it is conceivable that some of these signals converge directly within the chromatin, serving as initiators of epigenetic processes, including potential modifications in germ cells that may be inherited by offspring. Quantum principles might underlie this hypothetical biophotonic communication channel, perhaps through coherence or entanglement of photons. The primary challenge, of course, lies in explaining how such coherence could be maintained in the warm, noisy environment of biological systems. It may be that biophotons are not entangled in the strict quantum sense, but instead exploit other quantum properties such as spin selectivity or tunneling. Alternatively, protective or ordering mechanisms within chromatin could help preserve coherence long enough for effective signaling. A fascinating possibility is also that, exactly as in quantum communication technologies, redundancy could

play a role: signals may be encoded through multiple photon emissions to ensure that some reach their intended molecular receiver, also explaining the increased production of biophotons in response to stress of physiological changes.

In summary, this speculative framework envisions the existence of a biophotonic communication channel in living organisms, where UPE acts as a quantum layer of intracellular signaling. Through the unique properties of photons, these ultra-weak emissions could function as highly specific initiators of biochemical and epigenetic cascades, with chromatin serving as both transmitter and receiver of information, bridging the physical and informational dimensions of life.

4.2 An Experimental Idea

A compelling experiment would test whether changes in UPE produced by an organism after a defined experience can be temporally and causally linked to specific epigenetic modifications in the DNA and perhaps in germline, and whether those changes are then reflected in offspring. The rationale rests on three empirical pillars: DNA and nuclei have been shown to emit UPE under physiological conditions, so the genome itself can be a photon source; plant and animal studies show that UPE changes reliably with environmental stress; and classic TEI work demonstrates that certain parental experiences produce heritable epigenetic marks and altered offspring phenotypes. Taken together, these facts motivate an experiment in which an induced parental experience (for example, an olfactory fear conditioning such as the acetophenone paradigm used by Dias and Ressler explained in section 2) is paired with simultaneous, time-resolved recording of UPE from the parent, followed by molecular analysis of epigenetic marks in DNA, in parental germ cells and behavioral/epigenetic assays in subsequent generations. The key measurements would be: a) whether UPE intensity, spectrum or temporal pattern changes reproducibly after the experience; b) whether those UPE changes precede, accompany or predict specific epigenetic modifications both in DNA and in sperm/eggs; c) whether offspring conceived after the experience show the expected phenotype and the same epigenetic signature. The experiment is fascinating but still technically demanding: UPE signals are extremely weak and require careful dark-room detection; timing and statistical power must be sufficient to link transient photonic events to later molecular changes; and ethical review is required for animal work. Furthermore, even if the experiment finds only correlation (UPE and epigenetic marks both change after stress), that would still be informative: the real search should focus, after positive result, on finding a true direct causality between the two processes, opening a new, photonic dimension to how life records experience and passes it on. Concluding this chapter, to test this hypothesis, but also more generally to uncover quantum signals in the world of biology, we need an interdisciplinary union between two worlds that are still too distant: experimental physics and biology. By initiating collaborations and experiments, even if initially unsuccessful, we could begin to build expertise in the field, which would certainly lead in the future to correct hypotheses and incredible discoveries, as much as those of quantum mechanics.

5. Conclusions

In conclusion, given the incredible potential of quantum information, and how the hypothesis of exchanging signals via (entangled) photons has changed our way of conceiving information exchange, bringing about a “quantum revolution” in the coming decades, it is more than reasonable to think that nature, and in particular our bodies, already adopt a similar method involving photons to communicate. This essay has, after reviewing what epigenetics and biophotons are, explored the possibility that the activation of DNA genes due to external factors and experiences is intrinsically linked to the exchange of information via photons. The hypothesis can be intuitively supported by two main factors: it has been shown that there is an abnormal production of biophotons precisely when a living being is subjected to stress and experiences, and epigenetic changes arise precisely from similar situations; Furthermore, it has been experimentally proven that DNA is a huge source of biophotons, opening up the possibility that there is some as yet unknown mechanism within it in which UPE occurs, and the link with the transmission of information, including epigenetic information, cannot be ruled out a priori. Finally, the essay emphasized that a possible experiment to explore this suggestion could combine observations of biophotons with a comprehensive study of DNA and epigenetic changes over time, in order to investigate an actual correlation between the two, which would at least prove

a link (even if not direct) between the two processes. In conclusion, it is tempting to speculate that nature has come before us in exploiting quantum communication, and it is precisely there that, in my opinion, we should look for underlying signals that would suggest the presence of quantum mechanisms at the basis of life. It is certainly fascinating to think that the building block of our survival could come from quantum mechanics; it may be that what sustains life is not only chemistry, but a hidden dialogue of photons shaping existence itself.