Biophotons: Definition, History, Measurement, and Relevance to Biofield Therapies — A Comprehensive Literature Review

A Scholarly Literature Review

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ABSTRACT

Biophotons — also termed ultraweak photon emissions (UPE) — are photons of non-thermal, non-bioluminescent origin spontaneously emitted by living biological systems. First described by Alexander Gurwitsch in the 1920s and formally conceptualized by Fritz-Albert Popp in the 1970s and 1980s, biophotons arise principally from reactive oxygen species (ROS) generated during oxidative metabolism, as well as from electronically excited molecular states in lipids, proteins, and DNA. Their radiant emittance is extraordinarily faint — typically 10^{-17} to 10^{-23} W/cm², equivalent to a few to several hundred photons per cm² per second — yet they are reproducibly detectable with modern high-sensitivity photomultiplier tubes, electron-multiplying charge-coupled devices, and single-photon avalanche diodes. The spectral range of UPE spans approximately 200–800 nm, covering the ultraviolet through the near-infrared. Research has established biological correlates of UPE with cellular oxidative state, metabolic activity, disease status, and neural function. More speculatively, Popp and colleagues proposed that biophotons constitute a coherent biological light field involved in intra- and intercellular communication; however, subsequent rigorous statistical analyses have not confirmed the coherence hypothesis to the level required for scientific consensus. Within the domain of complementary and integrative medicine, biophotons have been invoked as a putative physical substrate for biofield therapies such as Reiki, Therapeutic Touch, and Healing Touch. A small but growing body of empirical studies has measured elevated photon emission from the hands of biofield practitioners and has observed effects of Reiki treatment on cellular biophoton output. Notwithstanding these findings, methodological limitations, absence of large-scale replication, and unresolved mechanistic questions mean that the causal link between biophotons and the therapeutic efficacy of biofield modalities remains speculative. This review synthesizes the foundational science of biophotons, their measurement methodologies, their established and proposed biological roles, and the current state of evidence connecting them to biofield healing practices. We conclude by identifying priority areas for future rigorous investigation.

1. Introduction

Light is among the most fundamental carriers of information in the physical universe. That living organisms themselves generate light — without fire, fever, or fluorescent tagging — is a phenomenon both ancient in its observation and modern in its rigorous scientific characterization. The photons emitted by biological systems at rest, known variously as biophotons, biological autoluminescence, or ultraweak photon emissions (UPE), occupy the vanishingly dim end of the electromagnetic spectrum of biological radiation. They are, by most measures, imperceptible to the naked eye and detectable only with instruments of extraordinary sensitivity. Yet their existence is now firmly established, and their potential significance in cell biology, biophysics, medical diagnostics, and even consciousness research is increasingly the subject of peer-reviewed investigation.

The term "biophoton" was formally introduced by the German biophysicist Fritz-Albert Popp in 1984 to denote photons of non-thermal origin emitted by living cells — distinct from the well-characterized phenomena of bioluminescence (as in fireflies or deep-sea organisms) and thermal radiation, both of which are far more intense and arise from different physical processes (Popp et al., 1984). The story of biophoton research is, however, considerably older, tracing back to the Russian embryologist Alexander Gurwitsch, who in the 1920s described what he termed "mitogenetic radiation" — an invisible emission from living tissue that he proposed could influence cell division at a distance (Gurwitsch, 1923). This early work was largely dismissed or ignored by mainstream biology, partly because the technology for detection was insufficient, and partly because the claim fell outside the prevailing paradigm of purely biochemical cellular communication.

The intervening century has witnessed a slow but accelerating rehabilitation of interest in UPE, driven by advances in photon detection technology and a growing appreciation that living systems are fundamentally electromagnetic as well as chemical entities. The biomedical relevance of UPE is multidimensional: it provides a non-invasive window onto cellular oxidative metabolism; it may serve as a diagnostic biomarker for oxidative stress, disease progression, and environmental toxicity; and it offers a physically measurable substrate for theoretical models of non-chemical biological communication. In parallel, but in a domain with considerably greater evidentiary uncertainty, proponents of biofield therapies — including Reiki, Therapeutic Touch, and external Qigong — have invoked biophotons as a potential mechanism through which practitioners may interact with and influence the biological systems of their clients.

This literature review aims to provide a rigorous, evidence-based synthesis of the current scientific understanding of biophotons. Section 2 presents a detailed historical account. Section 3 defines biophotons and describes their physical and biological properties. Section 4 surveys the mechanisms of generation. Section 5 reviews detection technologies. Section 6 examines established and proposed biological roles. Section 7 addresses the contentious question of coherence. Section 8 evaluates the evidence pertaining to biophotons and biofield therapies.

Section 9 discusses methodological challenges and limitations. Section 10 offers conclusions and directions for future research.

2. Historical Background

2.1 Gurwitsch and Mitogenetic Radiation (1920s–1950s)

The intellectual lineage of biophoton research begins in 1923 with Alexander Gurwitsch (1874–1954), a Russian-Soviet embryologist working at the University of Moscow. In a now-classic experiment, Gurwitsch positioned the growing tip (meristematic zone) of one onion root — termed the "inducer" — perpendicular to the side of a second onion root — the "detector" — separated by a small gap. When a quartz barrier was interposed between the two roots, the detector root exhibited a statistically elevated rate of mitosis in the region facing the inducer tip, compared to roots shielded by opaque barriers (Gurwitsch, 1923). Gurwitsch concluded that the inducer was emitting a form of radiation capable of passing through quartz (which is transparent to UV light) but not through glass or opaque materials, and that this radiation stimulated cellular division in the receiver — hence the name "mitogenetic rays."

Gurwitsch proposed that the spectral character of mitogenetic radiation lay primarily in the ultraviolet range, approximately 190–260 nm. Subsequent work in his laboratory and by independent groups attempted to characterize this radiation more precisely, with early photomultiplier-based measurements in the 1950s providing the first instrumental confirmation that plant tissues could emit ultraviolet photons at extremely low intensities (Colli & Facchini, 1954, as cited in Mould et al., 2024). The scientific community's reception of Gurwitsch's claims was, however, deeply ambivalent. Some laboratories reported replication; others failed to reproduce the mitotic stimulation effect. The theoretical framework — that UV radiation emitted endogenously by one cell could influence the physiology of another — was considered extraordinary and was not integrated into mainstream biology. The advent of molecular biology in the 1950s and 1960s, with its emphasis on genetic and biochemical mechanisms, further marginalized biophysical approaches to cellular communication.

2.2 Re-emergence: Popp and the Establishment of Biophoton Science (1970s–1990s)

The modern scientific study of biophotons was largely inaugurated by Fritz-Albert Popp (1938–), a German theoretical biophysicist. Popp's initial interest arose from a different direction: investigating the carcinogenicity of polycyclic aromatic hydrocarbons. He observed in the 1970s that carcinogenic compounds, unlike their non-carcinogenic structural analogues, were distinguished by their ability to scramble UV photons — a property he connected to their disruption of a postulated endogenous photon field in cells (Popp, 1976, as summarized in Popp, 2003). This led him to develop highly sensitive photomultiplier tube (PMT) systems capable of detecting single-photon-level emissions from biological samples in complete darkness.

Popp's landmark 1984 paper, co-authored with colleagues, provided two central contributions to the field (Popp et al., 1984). First, it presented systematic evidence that cultured human cells emitted photons at rates orders of magnitude above thermal background, with an estimated output of approximately 1–100 photons per cm^2 per second in the visible-to-UV range. Second, and more controversially, it presented statistical arguments that this emission exhibited properties consistent with coherence — the photons appeared to be phase-correlated in a manner analogous to laser light, rather than exhibiting the random temporal distribution expected from thermally or chemically generated photons. Popp interpreted this coherence as evidence that biophotons originated from a coherent electromagnetic field stored in DNA, which he proposed served as the master regulator of biological organization and communication.

The 1980s and 1990s saw rapid expansion of the field internationally. Research groups in Germany, Japan, the Netherlands, China, South Korea, and elsewhere began measuring UPE from a wide range of biological systems, including plants, bacteria, fungi, animal tissues, and human skin. An important institutional development was the formation of the International Institute of Biophysics (IIB) in Neuss, Germany, founded by Popp in 1996, which coordinated biophoton research across multiple national laboratories. The multi-author review of 1988 — including contributions from Gurwitsch's own grandson — synthesized available data and articulated the emergent scientific consensus that biophotons were a real and universal phenomenon of living matter (Popp et al., 1988).

2.3 Recent Decades: Technology, Imaging, and Biomedical Applications (2000s–Present)

Advances in detector technology from the late 1990s onward transformed biophoton research from a niche biophysical curiosity into a field with concrete biomedical applications. The introduction of electron-multiplying charge-coupled devices (EM-CCD) and cooled CCD cameras enabled two-dimensional imaging of UPE from intact biological specimens, including whole organisms. The group of Masaki Kobayashi published striking in vivo images of spontaneous photon emission from rat brains and bodies, demonstrating spatial correlations with known metabolic and physiological gradients (Kobayashi et al., 1999). A landmark study by Kobayashi and colleagues further demonstrated that the human body emits a dim visible glow that fluctuates in a circadian pattern, with emission being lowest in the early morning and peaking in the afternoon (Kobayashi et al., 2009).

The period from 2010 to the present has seen biophoton research become increasingly mainstream, with publications appearing in high-impact journals including Scientific Reports, PLOS ONE, Frontiers in Physiology, and iScience. The scope of investigation has expanded to include biophoton emission from neural circuits and the brain, the role of UPE in inter-organismal communication, its potential as a diagnostic biomarker for cancer and oxidative stress disorders, and — in the most recent literature — the use of photoencephalography as a novel modality for non-invasive brain monitoring (Mould et al., 2024; iScience, 2025). The 2024 review by Mould and colleagues at the University of Westminster, published in Frontiers in Physiology, represents a notable synthesis of the state of the art, covering mechanisms, detection, biological roles, and medical applications within a rigorous scientific framework.

3. Definition and Physical Properties of Biophotons

3.1 Formal Definition

A biophoton is defined, following Popp et al. (1984), as a photon of non-thermal origin emitted from a biological system in the visible to ultraviolet spectral range, which is distinguishable from thermally generated blackbody radiation, from classical bioluminescence (e.g., luciferase-mediated reactions in fireflies), and from delayed luminescence (the photon emission that occurs after photoexcitation and decays over seconds to minutes). The term "ultraweak photon emission" (UPE) is now frequently preferred in the peer-reviewed literature — particularly by groups emphasizing the physical rather than informational aspects of the phenomenon — because it is more operationally precise and avoids the teleological connotations sometimes associated with "biophoton" (Cifra et al., 2014; Mould et al., 2024). Both terms are used interchangeably in this review, consistent with common practice in the field.

Biophotons must be distinguished from three related but distinct phenomena: (i) thermal radiation, which is emitted by any object above absolute zero and follows Planck's blackbody law; (ii) bioluminescence, which involves enzyme-mediated, high-yield photon production (e.g., the luciferin-luciferase system) and produces emission intensities many orders of magnitude higher than UPE; and (iii) delayed luminescence (DL), which is photon emission following photoexcitation that decays hyperbolically over time and reflects the relaxation of excited electronic states. Unlike DL, UPE occurs without prior external photoexcitation and represents a truly spontaneous emission arising from endogenous biochemical processes.

3.2 Intensity and Spectral Properties

The intensity of biophoton emission from biological tissues is extraordinarily low. The typical radiant emittance falls in the range of 10^{-17} to 10^{-23} W/cm², corresponding to approximately 1 to 1,000 photons per cm² per second in the spectral window of 200–800 nm (Cifra et al., 2014; Wikipedia: Biophoton). For reference, this is roughly 10 to 100 million times weaker than a candle observed from one meter. This intensity places biophoton detection at the absolute frontier of optical instrumentation, requiring near-complete elimination of ambient light and electronic noise.

The spectral distribution of UPE is broad and continuous, extending from the near-ultraviolet (approximately 200 nm) through the visible range and into the near-infrared (to approximately 800 nm or beyond). The spectrum does not correspond to any single molecular transition; rather, it reflects a superposition of emissions from multiple electronically excited chemical species, including excited carbonyl groups (C=O*), singlet oxygen ($^1O_2$), and excited triplet states of various biomolecules. The relative contribution of different wavelength bands varies with tissue type, metabolic state, and experimental conditions. Some researchers have reported that UPE from cancer cells exhibits a distinct spectral profile compared to normal cells, raising the possibility of spectroscopic discrimination for diagnostic purposes (Kobayashi et al., 2009; Scordino et al., 2014, as cited in Mould et al., 2024).

3.3 Temporal Dynamics

Biophoton emission is not static but varies in time in accordance with the metabolic state of the organism. Diurnal rhythms in UPE from human skin have been documented, with peak emission occurring in the afternoon and minimum emission in the early morning hours — patterns consistent with circadian regulation of oxidative metabolism (Kobayashi et al., 2009). Seasonal variation has also been reported in year-long measurements from human subjects, potentially reflecting changes in antioxidant status, photoperiod, or other environmental factors (van Wijk & van Wijk, 2005, as cited in Mould et al., 2024). In response to physiological challenges such as heat shock, oxidative stress, or pharmacological interventions, UPE intensity increases measurably and in a dose-dependent manner, making it a sensitive indicator of cellular stress (Cifra et al., 2014; Mould et al., 2024).

4. Mechanisms of Biophoton Generation

4.1 Reactive Oxygen Species and Oxidative Metabolism

The most scientifically well-established and widely accepted mechanism of biophoton generation is the spontaneous emission from electronically excited molecular species produced during normal aerobic metabolism. Living cells continuously consume oxygen in mitochondrial respiration, generating reactive oxygen species (ROS) — including superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), and hydroxyl radicals (•OH) — as byproducts of the electron transport chain. Under conditions of oxidative stress, these ROS accumulate and undergo a series of reactions that produce electronically excited molecules at ground state plus one or more quantum energy levels above the molecular ground state (Pospíšil et al., 2014).

The primary ROS-linked photon-generating reactions include: (a) lipid peroxidation, in which polyunsaturated fatty acids undergo radical chain reactions producing excited carbonyl compounds that de-excite by emitting a photon in the visible range; (b) the decomposition of dioxetane intermediates, formed during lipid peroxidation or enzyme-catalyzed oxidations, which yield excited carbonyl products; and (c) singlet oxygen ($^1O_2$) formation — singlet molecular oxygen can be generated by the Russell mechanism during lipid peroxidation and emits characteristic photons at 634 nm and 703 nm upon radiative de-excitation; and (d) excitation of endogenous fluorophores such as NADH, flavins, and porphyrins by ROS (Cifra et al., 2014; Pospíšil et al., 2014).

This well-understood mechanistic pathway explains why UPE intensity correlates robustly with markers of oxidative stress and metabolic rate across a wide range of biological systems — from bacteria and yeast to mammalian tissues and whole organisms. In healthy, unstressed cells, the efficient antioxidant system (superoxide dismutase, catalase, glutathione peroxidase) minimizes ROS accumulation, and UPE is accordingly low. Heat shock and other stressors that transiently overwhelm antioxidant defenses produce measurable, transient increases in UPE (Mould et al., 2024). This mechanistic clarity gives UPE its utility as a non-invasive biomarker for oxidative processes.

4.2 DNA as a Source of Biophotons

Fritz-Albert Popp proposed, and subsequently investigated through multiple experimental approaches, that DNA is not merely a passive recipient of biophotonic radiation but is itself a primary source and storage medium for biophotons within the cell (Popp et al., 1984). The hypothesis rests on the observation that DNA intercalation by compounds that alter its photophysical properties — notably ethidium bromide — produces corresponding changes in UPE statistics (Popp, 2003). More recently, a 2024 study published in Scientific Reports provided direct evidence that DNA emits photons under physiological conditions and temperatures, observing that even under baseline conditions DNA can occasionally emit light before returning to a non-fluorescent state for extended periods (Nature Scientific Reports, 2024). The authors noted that the emission of DNA-derived biophotons exhibits quasi-periodic burst patterns, drawing an analogy to binary data transmission in noisy channels — language evocative of Popp's information-theoretic framework, though more measured in its interpretive claims.

The role of DNA in biophoton storage and regulation — as opposed to merely contributing to emission — remains mechanistically unresolved. Popp's model, drawing on quantum optics, envisioned DNA as operating as an exciplex laser: a coherent optical cavity capable of trapping and re-emitting photons in a phase-correlated manner. While this model remains theoretically stimulating, the evidence for DNA functioning as an optical cavity of the required quality is indirect and has not been validated by independent structural or spectroscopic measurements that would be expected from a confirmed laser-like system.

4.3 Mitochondria, Proteins, and Other Sources

Beyond ROS and DNA, several additional intracellular sources contribute to the overall biophoton signal. Mitochondria are both the primary generators of ROS in eukaryotic cells and, accordingly, the dominant subcellular source of UPE. The high density of unsaturated membrane lipids in the inner mitochondrial membrane provides an abundant substrate for lipid peroxidation and the associated photon-generating reactions. Proteins, particularly those containing aromatic amino acids (tryptophan, tyrosine, phenylalanine) capable of absorbing and re-emitting UV photons, also contribute to the UPE spectrum. Plasma membrane lipids and cytoskeletal components, including microtubules (whose tubulin dimers have been proposed as quantum-coherent entities in some consciousness research frameworks), have been proposed as secondary sources and modulators of intracellular biophotonic activity (Cifra et al., 2011, as cited in Kent et al., 2020).

5. Detection and Measurement Technologies

5.1 Photomultiplier Tubes

The photomultiplier tube (PMT) has been the workhorse of biophoton detection since the 1950s and remains the most widely deployed technology in the field. A PMT operates on the photoelectric effect: an incident photon strikes a photosensitive cathode, liberating a photoelectron that is then amplified through a cascade of dynodes (secondary electron multipliers) to yield a measurable electrical pulse at the anode. Modern bialkali PMTs, such as the Hamamatsu H7360 series widely used in biophoton research, can achieve dark count rates below 20 counts per second at room temperature, with quantum efficiencies of 20–30% across the visible range. Cooling the photocathode to -20°C or below can further reduce dark counts to near-single-digit levels per second, dramatically improving the signal-to-noise ratio for extremely weak sources.

The standard experimental setup for PMT-based biophoton measurement consists of a light-tight dark chamber — typically lined with non-reflective black material to eliminate photon scattering — in which the biological sample is placed in close proximity to the photocathode face. Temperature is rigorously controlled to prevent thermal drift. The PMT output is processed in photon-counting mode (rather than current mode), wherein each single-photon pulse above a discriminator threshold is registered as a count. Data are typically recorded as photon counts per unit time interval (e.g., per second or per 10-second bin), yielding a time series from which temporal dynamics, circadian patterns, and responses to interventions can be analysed (Cifra et al., 2014; Mould et al., 2024; arxiv:2401.17166, 2024).

5.2 Two-Dimensional Imaging with CCD and EM-CCD Cameras

A significant technological advance in biophoton research was the introduction of two-dimensional photon imaging using highly cooled CCD and EM-CCD cameras. These devices employ megapixel arrays of photodetectors, enabling spatial mapping of biophoton emission across the surface of biological specimens — a capability entirely absent from single-PMT measurements, which yield only a total integrated photon count over the detector area. EM-CCD cameras are specifically engineered for single-photon-level imaging: the electron-multiplying register amplifies charge before readout, dramatically reducing the relative noise contribution of the readout electronics. Long integration times (from seconds to minutes) are accumulated in darkness, producing false-colour images of photon emission intensity that can be overlaid on white-light reference images of the specimen.

This imaging modality has produced some of the most visually compelling data in the field. Kobayashi et al. (2009) used a cooled CCD camera to image spontaneous photon emission from the faces and hands of five healthy male volunteers over multiple imaging sessions, demonstrating both spatial patterns of emission and their circadian variation. Similarly, imaging of plants under stress, of mice in vivo, and of isolated tissues and organs has revealed heterogeneous spatial patterns of UPE that correspond to known physiological gradients (Kobayashi et al., 1999; Mould et al., 2024). Two-dimensional UPE imaging has also been applied to discriminate between cancerous and normal tissue ex vivo, based on the characteristically elevated emission from metabolically hyperactive tumor cells.

5.3 Single-Photon Avalanche Diodes and Emerging Technologies

Single-photon avalanche diodes (SPADs), or single-photon avalanche detectors, represent a more recent addition to the biophoton detection toolkit. SPADs are semiconductor devices that, when biased above their breakdown voltage, can register individual photon arrivals with high timing resolution (< 1 nanosecond) and quantum efficiencies exceeding 50% at visible wavelengths — substantially higher than conventional PMTs. Their compact form factor, low operating voltage, and compatibility with silicon chip fabrication make them attractive for future miniaturized or implantable biophoton measurement devices. The 2022 Scientific Reports study demonstrating that photons guided by myelinated axons may enable backpropagation-based learning mechanisms in the brain used SPAD-based detection in combination with optical waveguide models of neural tissue (Scientific Reports, 2022).

Complementary detection approaches include fiber-optic coupled PMT systems for in vivo or ex vivo tissue measurements, hyperspectral imaging systems for simultaneous UPE measurement across multiple wavelength bands, and time-correlated single photon counting (TCSPC) for measuring photon emission lifetime — a parameter that can discriminate between different molecular sources of UPE. The field is increasingly moving toward multimodal platforms that combine UPE measurement with concurrent recording of EEG, metabolic parameters, or molecular markers, to better characterize the biological correlates and functional significance of biophoton emission (iScience, 2025).

6. Established and Proposed Biological Roles of Biophotons

6.1 Biomarker of Oxidative Stress and Metabolic State

The most rigorously established biological correlate of UPE is the cellular oxidative state. Numerous independent research groups have demonstrated robust, quantitative relationships between UPE intensity and established markers of oxidative stress, including levels of lipid peroxidation products (malondialdehyde, 4-hydroxynonenal), antioxidant enzyme activity, glutathione concentration, and mitochondrial membrane potential (Cifra et al., 2014; Pospíšil et al., 2014). These correlations have been demonstrated across diverse biological systems, from isolated cell cultures and tissue homogenates to whole living organisms, and are consistent with the mechanistic model described in Section 4.

This established relationship has practical implications for medical diagnostics and pharmacological monitoring. Because UPE is non-invasive, label-free, and does not require destructive sampling, it offers a theoretically attractive modality for real-time, continuous assessment of oxidative stress in living tissue. Studies have demonstrated the utility of UPE measurement in discriminating between normal and cancerous tissues — a finding replicated by multiple groups for lung, colon, breast, and bladder cancer tissue (Amano et al., 1995; Musumeci et al., 2005; Scordino et al., 2014, as cited in Mould et al., 2024). A systematic review of the peer-reviewed literature on UPE from humans, published in ScienceDirect (van Wijk et al., 2004), concluded that there is sufficient evidence to pursue UPE-based health assessment as a research agenda, while calling for standardized protocols, larger sample sizes, and blinded designs.

6.2 Neural Biophotons and Brain Function

A particularly active and scientifically intriguing sub-field concerns the potential role of biophotons in neural signaling and brain function. Tang and Dai (2014) developed an in vitro biophoton imaging method using mouse brain slices and demonstrated that glutamate application — a major excitatory neurotransmitter — produces a gradual, sustained increase in biophotonic activity in coronal brain slices, which was partially inhibited by oxygen-glucose deprivation and cytochrome c oxidase inhibition, implicating mitochondrial oxidative metabolism as the source (Tang & Dai, 2014). The same group showed that biophotonic activity in neural circuits exhibits spatial propagation patterns consistent with neurotransmission pathways, and subsequently provided evidence that biophotons may be transmitted through neural fibres using myelinated axons as optical waveguides — a physically feasible mechanism given the refractive index properties of myelin (Sun et al., 2010, as cited in Mould et al., 2024).

A landmark 2022 paper in Scientific Reports modelled the propagation of photons through myelinated axons and proposed a specific computational role: photons guided by axons could enable a form of backpropagation-based synaptic learning, providing a light-based complement to chemical and electrical signaling in neural circuits (Scientific Reports, 2022). While this remains a theoretical proposal requiring experimental confirmation, it represents the kind of integrative modelling that bridges biophoton physics with contemporary neuroscience. More recently, the iScience paper of 2025 described "photoencephalography" — the measurement of UPE from the scalp surface as a non-invasive probe of brain metabolic and functional activity — finding that UPE patterns change with cognitive state and are dominated by low-frequency oscillatory components below 1 Hz, distinct from conventional EEG signals (iScience, 2025). Concurrently, a ScienceDirect review of 2024 synthesized evidence linking alterations in UPE to oxidative stress and mitochondrial dysfunction in neurodegenerative diseases, proposing that UPE measurement could serve as a novel biomarker for Alzheimer's disease, Parkinson's disease, and related conditions (ScienceDirect, 2024).

6.3 Intercellular and Interorganismal Communication

A more speculative — though experimentally investigated — role for biophotons is in direct cell-to-cell or organism-to-organism communication via photon exchange. Fels (2009) conducted carefully controlled experiments in which unicellular organisms (Paramecium caudatum) were placed in compartments separated by a quartz window transparent to UV photons or by a glass window opaque to UV. Cell growth rates differed in a manner consistent with photon-mediated communication across the quartz but not the glass barrier — a conceptual replication of Gurwitsch's original mitogenetic ray experiments using modern controls (Fels, 2009, as cited in Mould et al., 2024). Similarly, Mothersill and colleagues at McMaster University investigated "bystander effects" in irradiated cells — the observation that unirradiated cells respond to signals from irradiated neighbors — and presented evidence consistent with photon-mediated information transfer between cells (Mothersill et al., 2013, as cited in Speculations about Bystander and Biophotons, PMC4267444).

These inter-cellular communication experiments remain at the frontier of the field and have not achieved broad independent replication at the level that would secure consensus acceptance. The physical plausibility of photon-mediated communication over cell-scale distances is, however, not unreasonable: even at the low photon densities characteristic of UPE, a single photon absorbed by a chromophore in an adjacent cell can trigger significant biochemical downstream signaling if the absorber is a light-sensitive enzyme or regulatory molecule. The challenge is establishing that such absorption is not merely incidental but is physiologically regulated and functionally meaningful.

7. The Coherence Hypothesis: Evidence and Critique

One of the most intellectually significant — and scientifically contentious — aspects of biophoton research is Fritz-Albert Popp's coherence hypothesis. Popp proposed that biophotons are not simply the random photonic debris of metabolic chemistry, but rather constitute a highly ordered, coherent electromagnetic field within living organisms, with properties analogous to laser light. In quantum optics, a coherent light field is one in which the phase relationships between photons are fixed — a property that gives laser light its directionality, interference capability, and information-carrying capacity. Popp argued that the statistical distribution of biophoton emission events — specifically, the photon count statistics — deviated from a Poissonian distribution in a manner indicative of a "squeezed" or sub-Poissonian light state, a hallmark of non-classical (coherent) photon fields (Popp, 2003; Popp, 1999).

The implications of this hypothesis, if confirmed, would be profound: a coherent biophoton field could serve as an organism-wide regulatory signal operating at the speed of light, carrying encoded biological information from DNA through the organism. This framework has appealed to researchers interested in holistic models of biological organization and has been invoked, as discussed in Section 8, in the context of energy healing modalities.

However, a comprehensive 2015 critical review by Cifra, Brouder, Nerudová, and Kučera — published in the Journal of Luminescence — specifically re-examined all experimental claims for biophoton coherence and found them wanting (Cifra et al., 2015). The authors categorised prior studies into those with conventional, statistically sound interpretations and those with unconventional, speculative interpretations. Their central conclusion was unambiguous: while the phenomenon of UPE from biological systems can be considered experimentally well established, no reliable evidence for the coherence or non-classicality of UPE had been achieved as of that writing, and many of the statistical analyses claiming to demonstrate coherence were methodologically flawed (Cifra et al., 2015). A companion commentary by Salari and Brouder further challenged specific claims about delayed luminescence coherence (Salari & Brouder, as cited in Scientific Reports, 2020).

This critical reassessment does not negate the existence or significance of biophotons — the UPE phenomenon itself is scientifically robust and independently confirmed. What it does challenge is the specific information-theoretic and holistic regulatory framework built on the coherence claim. As Mould et al. (2024) summarise, biophoton research has been "historically hamstrung" not only by detection limitations but also by overinterpretation of limited data, and progress requires distinguishing experimentally established findings from theoretical extrapolations. The coherence question remains open but unresolved in favour of non-classical emission, pending experiments specifically designed to test coherence with modern quantum optical methods.

8. Biophotons and Biofield Therapies

8.1 Defining the Biofield

The term "biofield" was formally introduced into scientific discourse in 1992 by an expert committee convened by the newly established Office of Alternative Medicine at the US National Institutes of Health (NIH), which defined it as "a massless field, not necessarily electromagnetic, that surrounds and permeates living bodies and affects the body" (as cited in Rubik, 2002; Rubik et al., 2015). This deliberately broad definition was intended to provide a common scientific language for discussing diverse complementary medicine practices — including Reiki, Therapeutic Touch, Healing Touch, external Qigong, and Johrei — that postulate the existence of an energetic dimension to biological organisms. In 1994, the NIH further defined biofield therapies as "noninvasive, practitioner-mediated therapies that explicitly work with the biofield of both the practitioner and client to stimulate a healing response in the client."

The biofield concept deliberately encompasses physically measurable aspects of biological electromagnetic activity — including the body's electric and magnetic fields, detectable as ECGs, EEGs, MCGs, and MEGs — alongside the more hypothetical aspects of subtle energy as conceived in traditional healing systems (Rubik, 2002; Hintz et al., 2003, as cited in PMC4654783). Biophotons, as spontaneously emitted photons from every living cell, constitute one physically demonstrable component of the biological electromagnetic environment, and their inclusion within a broader biofield framework is scientifically legitimate. The question addressed in this section is more specific: does the empirical evidence support a causal role for biophotons in the mechanisms or therapeutic effects of biofield healing practices?

8.2 Clinical Evidence for Biofield Therapies

Before addressing the biophoton-specific question, it is important to characterise the clinical evidence base for biofield therapies overall. A systematic review by Jain and Mills (2010), published in the International Journal of Behavioral Medicine, examined 66 clinical studies of biofield therapies across diverse patient populations (Jain & Mills, 2010). The authors performed quality assessment alongside a best-evidence synthesis approach. Their findings indicated that biofield therapies show strong evidence for reducing pain intensity in pain populations, moderate evidence for reducing pain in hospitalized and cancer patients, and moderate evidence for reducing agitated behaviours in dementia and anxiety in hospitalized patients. The studies were of medium overall quality and generally met minimum standards for inferential validity, but were noted to suffer from small sample sizes, inconsistent blinding, and lack of standardization of intervention protocols.

Subsequent systematic reviews and meta-analyses have partially replicated and extended these findings. A 2014 meta-analysis of Reiki studies found significant positive effects on pain, anxiety, and depression across randomized controlled trials, though the effect sizes were modest and publication bias could not be excluded (Thrane & Cohen, 2014, as cited in Kent et al., 2020). A 2017 integrative review of Reconnective Healing — a related biofield modality — by Baldwin and Trent, published in The Journal of Alternative and Complementary Medicine, concluded that there is preliminary evidence for physiological effects measurable by objective instruments, including altered brainwave patterns, heart rate variability changes, and measurable field perturbations, but emphasized the need for larger, better-controlled trials (Baldwin & Trent, 2017).

Critically, the mechanisms by which biofield therapies may produce therapeutic effects — whether through relaxation response, placebo and expectation effects, specific energetic interactions, or some combination thereof — remain unclear. This mechanistic ambiguity is not unique to biofield therapies: many physically established medical interventions lack complete mechanistic explanations. However, the extraordinary claims made by some practitioners and researchers — specifically the claim that practitioners can detect and manipulate a subtle energy field that is not reducible to known physical forces — impose a correspondingly high evidentiary burden (Jain & Mills, 2010).

8.3 Biophoton Emission from Biofield Practitioners

Several studies have measured biophoton emission specifically from the hands of healers and biofield therapy practitioners, seeking to identify measurable physical correlates of the practitioner's energetic output. Rubik et al. (2006) conducted measurements of biophoton emission from the palms of biofield therapy practitioners before and during the performance of their practice, using PMT-based detection in a dark chamber. They reported a statistically significant increase in biophoton emission from the palms pre-treatment compared to post-treatment and observed a trend suggesting that a practitioner's conscious intent to increase emission could produce the expected effect (Rubik et al., 2006, as cited in Kent et al., 2020). This finding, if robustly replicated, would imply that biofield practitioners emit measurably more photons from their hands than non-practitioners or individuals not engaged in healing intent, providing an objective physical signature of the practitioner state.

A related study by Kobayashi et al. measured UPE from the hands of 20 healthy subjects, finding approximately 34% more biophotons in the 300–650 nm range from the hands than from background, but no statistically significant difference between palms and the backs of the hands, and no marked dependence on age or gender (Kobayashi, as cited in ResearchGate: Biophoton emission from the hands). This baseline characterization is important for contextualizing practitioner studies — the hands naturally emit measurable UPE, and any claimed enhancement by healing intent must exceed this baseline by a statistically and practically significant margin.

A 2017 paper by Bhatt, Bhatt, and colleagues specifically examined the effects of intention, energy healing, and mind-body states on biophoton emission, synthesizing available data across meditation, Qigong, and biofield therapy studies. The authors noted that biofield therapy practitioners with intent to heal show measurable increases in UPE from their hands, particularly in the ultraviolet range (ultraviolet photons constituting approximately the range studied by Gurwitsch). They also observed an apparent divergence between meditation — which tended not to increase biophoton output — and active healing intent, suggesting that the direction of mental attention (inward for meditation versus outward for healing) may modulate photon emission in different ways (Bhatt et al., 2017, as cited in ResearchGate: Effects of intention, energy healing). The sample sizes in these studies were uniformly small, blinding procedures varied, and independent replication is limited.

8.4 Effects of Biofield Therapies on Cellular Biophoton Emission

The most methodologically innovative study to date connecting Reiki and biophoton measurement at the cellular level was conducted by Kent, Jin, and Li, published in Global Advances in Health and Medicine in 2020 (Kent et al., 2020; PMC7676814). The investigators treated mouse intervertebral disc (IVD) cells with ten-minute sessions of Reiki or sham treatment administered by a trained practitioner on three successive days. During treatment, the cells were housed in a custom-constructed light-tight box equipped with a PMT, allowing real-time photon counting from the cellular preparation while the practitioner's hands were positioned beneath the cell plate through cutouts in the box. Sham treatment was performed by a non-Reiki-trained individual who mimicked the hand positions.

The results showed that Reiki significantly increased photon emission from the cells post-treatment compared to both the Reiki pre-treatment baseline and the sham condition ($p < 0.05$).

Concurrent molecular analysis by real-time PCR showed significant increases in collagen II and aggrecan expression ($p < 0.05$), markers of anabolic extracellular matrix synthesis suggesting a reparative cellular response. The authors interpreted the post-treatment biophoton increase as potentially reflecting delayed luminescence — the store-and-release of photons by the cells in response to the Reiki interaction — rather than ongoing metabolic emission, and proposed that biophoton measurement could serve as an objective means of quantifying biofield therapy effects (Kent et al., 2020).

This study, while notable for its methodological rigor relative to prior work in the field, carries important caveats. The sample size was small, involving a limited number of experimental replicates. The mechanism by which Reiki treatment — which does not involve physical contact and operates at a distance of several centimeters through the box walls — could alter cellular photon emission or gene expression is not established. The possibility of artifacts from heat emitted by the practitioner's hands, infrared radiation, or subtle vibration transmitted through the experimental apparatus cannot be fully excluded without additional controls. The study has not, to the authors' knowledge, been independently replicated at the time of this review.

8.5 Theoretical Frameworks Connecting Biophotons to Energy Healing

Several theoretical frameworks have been proposed to account for how biophotons might mediate or be modulated by biofield healing practices. Popp's coherence model (see Section 7) remains the most frequently invoked: if biophotons in living organisms form a coherent field analogous to laser light, then a practitioner's own biophotonic field might interact constructively or disruptively with a patient's field through quantum optical interference, thereby influencing biological regulatory processes. This model has surface plausibility as a physical narrative but lacks the experimental foundation of demonstrated coherence in either practitioner or patient biophoton emission at the required spatial and temporal scales.

An alternative, less extraordinary framework invokes simply the thermal and electromagnetic environment of the hands: skilled, relaxed human hands placed near tissue will deliver warmth, infrared radiation, and low-level electromagnetic fields, all of which have demonstrated biological effects at the cellular level. Photobiomodulation (PBM, formerly low-level laser therapy) research has established that near-infrared photons delivered to tissue can modulate cytochrome c oxidase activity, mitochondrial electron transport, and downstream signaling cascades — effects that do not require quantum coherence (Hamblin, 2017, as cited in ScienceDirect Neurodegenerative Diseases review). If practitioner hands emit elevated near-infrared UPE during healing intent, these photons could, in principle, induce PBM-like effects in nearby tissue — a testable, mechanistically conservative hypothesis that does not require a "subtle energy" beyond known physics.

Biofield physiology, as articulated by Hintz, Yount, Kadar, Schwartz, and others in the complementary medicine research community, proposes a broader framework: electromagnetic, biophotonic, acoustic, and other fields generated by living systems constitute an integral layer of self-regulatory biological information that operates alongside and in concert with the better-studied molecular signalling networks (PMC4654783). Within this framework, biofield practitioners are not manipulating supernatural forces but are rather skilled at modulating measurable physical fields through trained states of consciousness, body posture, breath control, and focused intention. The therapeutic effects, on this account, arise through genuine field-mediated interactions that are in principle physically explicable but require more sensitive and specific instrumentation to characterise fully.

9. Methodological Challenges, Limitations, and Evidentiary Standards

Despite significant advances in both basic biophoton science and its application to biofield research, the field faces persistent methodological challenges that limit the certainty of conclusions.

Detection challenges: The extraordinary faintness of UPE imposes severe demands on experimental apparatus. Stray light contamination from ambient sources, phosphorescence from materials in the detection chamber, electronic noise from detector circuits, and even thermal radiation from the experimenter's body can all exceed the signal of interest if not scrupulously controlled. Temperature must be held constant, as thermal drift of even 0.1°C can produce detectable PMT artefacts. These requirements mean that well-executed biophoton experiments are technically demanding and not easily replicated without equivalent infrastructure and expertise.

Reproducibility and replication: The biophoton literature contains numerous small, single-laboratory studies that have not been independently replicated. This is particularly true for studies measuring the effects of mental states, intention, or healing practices on UPE. While the basic phenomenology of UPE — its existence, its correlation with oxidative stress, its circadian variation — has been independently replicated by many groups worldwide, the more extraordinary claims about coherence, intercellular communication, and practitioner-mediated effects have far fewer independent confirmations.

Control conditions: Studies involving human subjects as sources or targets of UPE face particular challenges in establishing adequate controls. In practitioner studies, matching the physical proximity of healer hands with non-healer hands (for sham conditions) while controlling for infrared radiation, warmth, and subtle mechanical effects requires sophisticated experimental design. Few existing studies have achieved all of these control conditions simultaneously.

Sample sizes and statistical power: The majority of published biophoton studies, especially those involving human subjects or therapeutic interventions, have sample sizes of five to twenty individuals — well below the thresholds required for robust statistical inference in light of the typically small effect sizes observed. Publication bias in a field where positive results are more likely to be published further inflates the apparent effect sizes in the literature.

Mechanistic specificity: Even where UPE changes are robustly documented in association with biofield treatments, the lack of established molecular or physical mechanism renders interpretation ambiguous. An increase in cellular photon emission post-Reiki could reflect, among other possibilities, increased oxidative activity, altered mitochondrial membrane potential, photobiomodulation from the practitioner's hands, placebo-mediated autonomic arousal in the cell preparation (if in vivo), or measurement artifact. Discriminating among these alternatives requires mechanistically targeted experimental designs that have rarely been deployed.

Evidentiary standards: The application of the highest standards of evidence-based medicine — including preregistered randomised controlled designs, adequate blinding, independent replication, and mechanistic elucidation — to biophoton-based biofield research is still in its infancy. The field would benefit from the adoption of consensus reporting standards, analogous to those developed by NCCIH for biofield therapy clinical trials, for biophoton measurement studies (NCCIH, 2022, as referenced in WellnessPlus).

10. Conclusions and Future Directions

Biophotons — ultraweak photon emissions from living biological systems — represent a scientifically established biophysical phenomenon with a rich and evolving research history. Beginning with Gurwitsch's intuitive experiments in the 1920s and given systematic scientific form by Popp and colleagues from the 1970s onward, biophoton research has now matured into an internationally active field with publications in high-ranking peer-reviewed journals, dedicated research institutes, and growing biomedical applications. The foundational biology is clear: biophotons arise principally from reactive oxygen species generated during aerobic metabolism, and their emission intensity faithfully tracks cellular oxidative state, making UPE a genuinely non-invasive, label-free biomarker for metabolic activity and oxidative stress.

The claims made for biophotons extend on a spectrum from the well-established to the highly speculative. At the established end: UPE is real, measurable, correlates with metabolic state, varies with disease and health, and can discriminate between cancer and normal tissue in ex vivo studies. At the contested but scientifically tractable end: biophotons may serve as signals in neural circuits, may mediate intercellular communication, and may be measurably elevated from the hands of biofield practitioners during healing intent. At the speculative end: the coherence hypothesis as originally formulated by Popp has not withstood rigorous scrutiny, and the specific claims for biophotons as a substrate for extraordinary or non-physical healing effects remain unsupported by the current evidence base.

With regard to biofield therapies specifically, the honest scientific verdict at this time is one of cautious, evidence-limited interest rather than either dismissal or endorsement. There is moderate clinical evidence that biofield modalities such as Reiki, Therapeutic Touch, and Healing Touch reduce pain and anxiety in some patient populations beyond what standard treatment alone achieves — effects that do not require exotic physical mechanisms and may be substantially mediated by the relaxation response, therapeutic alliance, and expectation effects inherent in any practitioner-patient interaction. There is preliminary, methodologically limited evidence that trained practitioners emit measurably elevated photon emissions from their hands during healing practice, and that direct exposure of cells to Reiki treatment produces measurable changes in photon emission and gene expression. Whether these UPE changes are causally connected to therapeutic outcomes, and whether they represent a genuinely distinct physical mechanism beyond ordinary thermal and infrared effects of hand proximity, cannot be concluded on current evidence.

Future research priorities in this field include: (1) large-scale, multi-site, pre-registered clinical trials of biofield therapies using standardised protocols; (2) mechanistically targeted experiments to discriminate between photobiomodulation, thermal, and "subtle energy" hypotheses for practitioner-cell interactions; (3) quantum optical experiments with sufficient sensitivity and precision to definitively test the coherence hypothesis for biological UPE; (4) development of standardised instrumentation protocols for biophoton measurement to enable cross-laboratory replication; (5) integration of UPE measurement with concurrent molecular (transcriptomic, proteomic, metabolomic) profiling to elucidate the signalling pathways downstream of biophotonic stimulation; and (6) in vivo human studies of UPE as a diagnostic biomarker for neurodegenerative and oxidative stress disorders, exploiting the emerging technology of photoencephalography.

Biophoton science sits at a productive, if intellectually demanding, frontier: simultaneously grounded in rigorous physics and open to extraordinary biological possibilities. Its future lies in disciplined experimental design, technological innovation, and the intellectual humility to distinguish what is known from what is hoped.

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