Perspectives in Biophotonics

Although wave-particle (photons-EM field) duality is a characteristic of the entire EM spectrum, the energy of photons below the frequency of visible light is so low that many refer to this as a region of waves rather than particles. Many of the physical characteristics of photons, such as size and shape, are illusive and debated in the scientific community. [1] The most widely accepted facts are that photons have no mass and their energy increases with frequency.

The Early History of Biophotonics

In the 1920s, Alexander Gurwitch, Professor of Histology,[2] asked why organs had a definite shape. He argued that chemical reactions are isotropic (the same in all directions) which means that chemistry can't determine shape. From experiments with plants, he concluded that 260 nm UV emissions, which he called "mitogenetic radiation," might regulate cell growth and differentiation.[3]

Gurwitsch was one of the greatest theoreticians of biology in this century. He and his followers transformed mitogenetic radiation into a powerful experimental technique for fundamental biological research, and mitogenetic radiation attracted worldwide scientific interest in the 1930s.

Unfortunately, mitogenetic radiation came under heavy attack at the same time as funds began pouring into molecular biology. The claim was made that the thousands of experiments conducted in Russia, France and Germany, demonstrating the mitogenetic effect, were 'wrong,' and that mitogenetic radiation simply 'does not exist,' because it could not be detected by instrumentation. After World War II, the whole subject of mitogenetic radiation nearly disappeared from view, at least in the West. [4]

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In the 1940s, L. Colli (Italy), T.I. Quickenden (Australia), Humio Inaba (Japan) and Alberto Boveris (USA) began experimenting with a newly devised photomultiplier (light detector) which accurately counted single photon emissions. They dropped the term "mitogenetic radiation," preferring "dark luminescence", "low level luminescence", "ultraweak bioluminescence", or "ultraweak chemiluminescence". These researchers proposed that photons emitted from living tissue were the result of oxidation and free radical reactions, and were therefore unimportant.[5]

The Biophotonic Model

In the 1970s, Fritz-Albert Popp discovered a much wider spectrum of photon emissions than had previously been recorded and coined the term "Biophoton'. [6] The energy released in assumed conventional processes, such as oxidation, and the reorganization of hydrogen bonds and Van der Waals complexes, is too low to excite electronic energy levels corresponding to the observed spectral range of ultra weak photon emissions (UPE), noted in various sources from 200 to 900 nm.[7]

In the 1980s, Popp found that two cells separated by an opaque barrier release biophotons in uncoordinated patterns. Remove the barrier and the cells soon begin releasing photons in synchrony. The cells, Popp concluded, were communicating by light.[8]

Popp found that carcinogenic substances absorb UV light (at 380 nanometers), and re-emit it with a changed frequency. He found that photo repair works most efficiently at 380 nm, He concluded that carcinogens must inhibit photo-repair, and if so, there must be some light in the body responsible for photo-repair. A prestigious journal on cancer agreed to publish his results. He was invited to speak to the world's leading cancer researchers. Popp's science was unassailable, except for one detail: it assumed that a weak light of 380 nm was being produced in the body, which most scientists refused to believe.

Popp also discovered the photons in the living systems he had examined were more coherent than anything he had ever seen. [9] From experiment, he showed that one of the most essential sources of biophoton emission was DNA; that the more DNA unwound, the higher the intensity of light, and also that DNA was capable of sending out a large range of frequencies. [10]

Modern conventional biology is still at a loss to adequately explain the process by which cell differentiation, migration, and integration occur with such speed and accuracy to form living organisms. [11] Popp believes that weak biophoton emissions are sufficient to orchestrate body processes, [12] and is the answer to the question of morphogenesis; the question of how living forms take shape. This is what Gurwitch originally argued for his mitogenetic radiation. Mitogenetic radiation is now considered ultraweak photon emission.

Results of other researchers have supported biophotonic theory, and in fact an *International Institute of Biophysics* (IIB) was founded, with about forty scientific groups worldwide focusing on biophotonic studies [13]. Although perhaps deserving of it, Popp is not yet on the list of Nobel prize winners. [14].

Although US participation in this effort is relatively small, in the early 1990s, Guenter Albrecht-Buehler, a biophysicist at Northwestern University Medical School in Chicago, demonstrated that cells can detect and respond to light from one another. Albrecht-Buehler believes cell's centrioles function as light detectors. He also believes the reason for this detection and response is that cells are talking to one another. [15]

Wave guide Coherence?

How might biological communication of biophotons occur? The alleged Bonghan corpuscle and duct system is gaining more credibility with independent research findings, providing an anatomical basis for the acupoint and meridian system. Bonghan ducts appear to supply the channels in the connective tissue with DNA granules inside, connecting acupoints in the skin to internal organs. As the narrow channels form a network of tubes with light sources, they can become an optical (fiber optic) channel which can produce a coherent photon state. [16] This is a scientific interpretation of acupuncture therapy. [17] This interpretation is supported by the fact that biophoton emissions have been recorded from acupuncture points during electro acupuncture. [18] Additional studies show a difference in optical properties and a difference in light propagation and reflectance between acupuncture points and meridians compared to surrounding skin. [19]

The collagenous liquid crystalline mesophases in connective tissue combined with the associated structured water constitutes a semi-conducting highly responsive network that extends throughout the organism. This network is directly linked to the intracellular matrices of individual cells, forming an excitable electric continuum for rapid intercommunication throughout the organism. Both the western DC electrodynamic field and the Chinese acupuncture system have a common anatomical basis. Both support rapid semiconduction of protons. Liquid crystal facilitates coherent excitations. Proton jump conduction is a form of semiconduction in condensed matter, and is much faster than conduction of electric signals by nerves. This collagenous 'ground substance' may form a much better intercommunication system than the nerves. [20]

Liquid crystals have been shown to mediate the properties of photonic crystals in optics.[21] Photonic crystals; ie. biophotonic crystals, have been detected in the human body. [22] Could biophotonic crystals and collagenous liquid crystalline mesophases in biology bear some analogy to liquid crystals and photonic crystals in optics?

liquid crystalline mesophases in connective tissue combined with the associated structured water

look at fn 20

Yasue et al have proposed a process whereby cyclical superradiance (long range coherence) occurs in the water molecules of the microtubule.
Quantum Brain Dynamics and Consciousness
Mari Jibu & Kunio Yasue
(John Benjamins, 1995)
Building on the quantum field theory developed in the 1960s by the Japanese physicist Hiroomi Umezawa, Kunio Yasue et al have developed a "quantum neurophysics" that explains how the classical world can originate from quantum processes in the brain. Yasue believes that several layers of the brain can host macroscopic quantum processes, whose quantum properties explain consciousness and cognition. http://www.scaruffi.com/mind/yasue.html.

Biophotons and consciousness?
Some theorists suggest that the notion of a common cellular language puts biophotons at the center not only of biological communication, but also of consciousness. Scott Hagan, a theoretical physicist at the British Columbia Institute of Technology in Burnaby, Canada, points out that we cannot think unless cells in the brain function simultaneously, as parts of a whole. In quantum physics, coherent states can act as a whole. Could the coherent biophotonic emissions from living tissue also act as a whole?

Hagan and Stuart Hameroff, associate director of the Center for Consciousness Studies at the University of Arizona, suggest that quantum coherence in the protein subunits of microtubules may give rise to consciousness . And, says Hameroff, biophotons could somehow control this process. [23]

Majid Rahnama at Shahid Bahonar University of Kerman in Iran et al, point out that neurons contain many light sensitive molecules. They hypothesise that microtubules can act as wave guides, channeling light from one part of a cell to another. They go on to suggest that the light channeled by microtubules can help to co-ordinate activities in different parts of the brain. [24] In the 1990s, Roger Penrose suggested that quantum processes in microtubules allowed coherence leading to consciousness. Could biophotons be that quantum process?

Trends in 21st century Science Media

New scientist provided an interesting article on biophotonics in 2002. Although generally aware of the research of Fritz Popp and Guenter Albrecht-Buehler, the article leans heavily toward the conventional interpretation of biophotons as an indication that certain oxidative reactions are occurring.

They note that in the 1980s, manufacturers such as Hamamatsu, a Japanese company specializing in photomultipliers, developed new highly sensitive instruments designed to record weak light signals. Keen to exploit this opportunity, and to seed a new bio-optics industry, the Japanese government funded a five-year, multibillion-yen research program into biophotons in 1986. [25] Dozens of researchers across Japan found these emissions coming out of everything from plant seeds to fruit flies. It was discovered that injured or stressed or diseased cells release far more photons than their healthy counterparts.

They also note that researchers are trying to develop ways to convert patterns of photon emissions into images of the body that resemble X-rays or CAT scans. However, cells are sensitive to many factors that alter the rate at which photons are emitted. This causes problems with reproducibility of results, even for relatively simple systems. [26] Apparently direct diagnosis of disease from biophotons will remain difficult without some technical or medical breakthrough. [27]

Interestingly, in 2010, MIT Tech Review looked briefly at biophotonics in a much more positive light. “In recent years, a growing body of evidence shows that photons play an important role in the basic functioning of cells.” And, “In fact, it looks very much as if many cells use light to communicate.” [28] The review concludes that biophotonics is one of the fastest moving and exciting fields in science today.[29]

From 1973, Herbert Fröhlich was professor of Solid State Physics at the University of Salford. He was among the first researchers to suggest that waves or vibration allow proteins to cooperate with one another and carry out instructions from DNA. [30]

Frohlich proposed that metabolic energy is not being lost as heat but stored in the form of coherent electromechanical vibrations called coherent excitations. These vibrations, now known as Frohlich Oscillations occur at the microwave and visible light frequency range of the electromagnetic spectrum. [31]

He showed that once energy reaches a certain level, molecules begin to vibrate in unison, until they reach a high level of coherence, when they may take on certain properties of quantum mechanics.[32]

Beneviste’s research, and homeopathy would seem to enter here

Oschman subscribes to the Piezoelectric / crystal / Semiconductor Model. He refutes the ‘bag model’ (of biological processes), in which molecular reactants in the enzymatic pathways move, meet, and react randomly. He maintains the cell is filled with filaments, tubules, fibers, and trabeculae, collectively called the cytoplasmic matrix or cytoskeleton--a network extending even to the genome. … Many of the enzymes once thought to be floating in the ‘soup’ are actually attached to structures within the cell nucleus. This provides an assembly line arrangement along which reaction sequences and frequencies can proceed rapidly. Furthermore, it serves as an integrated piezoelectric solid state system, thereby coordinating activities such as repair and defense as well as movement of nutrients, hormones, and toxins. Through the Hall effect, [33] it has been learned that the perineural system is sensitive to magnetic fields and that electronic semiconduction is occurring. This discovery confirmed Albert Saint-Gyorgyi's suggestion of semiconduction in the living matrix. [34]

Interestingly, the Mae-Wan HO/ Popp book was published in 1994. An entry in *The Journal of the Korean Physical Society* states: “Another possible application (of biophoton emission counts) is to evaluate the function of acupuncture meridians

because there are suggestive reports on the correlation between biophoton emission rates and the condition of the meridians. [35] The IIB paper was published sometime after 2007, [36] while the latest mainstream MRI studies are only now speculating that fascial connective tissue might be the anatomic basis for the acupuncture meridian system, as noted above.(ref?)

Obviously there is a significant delay between the time key research is done and the time by which it has been disseminated into the general scientific community. Much additional research undoubtedly will be done before this model is even generally acknowledged.

Regardless of skepticism, biophotons, bioelectrodynamics and biocommunication have become an established area of scientific inquiry. [37]

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[1] Science forums discuss the physical properties of photons:
http://www.scienceforums.net/topic/27337-does-a-photon-have-physical-volume-or-geometrical-size/
http://www.physicspost.com/physicsforums/topic.asp-ARCHIVE=&TOPIC_ID=2536.htm

Scientific paper:
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6TVN-470N734-XW&_user=10&_coverDate=01%2F24%2F1972&_rdoc=1&_fmt=high&_orig=search&_origin=search&_sort=d&_docanchor=&view=c&_searchStrId=1621382554&_rerunOrigin=google&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=9416e4665c139278ce009a7249426c0d&searchtype=a

Abstract
We attempt to clarify the question of the effective size of a photon on the basis of a physical picture which has been found useful in understanding the “shadowing” effects in nuclear photoprocesses and the diffractive features in both high energy nucleonic photoprocesses and large $\omega \equiv 2M\nu/Q^2$ nucleonic electroproductions. The result is in contradictions with the result of Cheng and Wu's model calculation and with the formal estimate of important space-time regions, in the law ω region. Origins of this disagreement are analyzed.

Physics letters B Volume 38 1972 Issue 2 p. 100-104
Published by Elsevier Science

A good summary:
http://www.oxygraphics.co.uk/photons.htm

[2] from 1918-1924 at Taurida University (Now Crimean University) in Crimea

[3] In his signature experiment, two onion roots were arranged at right angles to one another with the horizontal root (Inductor) pointed towards the vertical stem (Detector), with a space between the two for either normal window glass or quartz glass plate. Gurwitch recorded the rate of cell division (mitosis) on the detector. With window glass, no cell division occurred, whereas with quartz glass, cell division increased significantly. Gurwitch was aware that normal window glass blocks UV rays and quartz glass plate is transparent for UV light of about 260 nm.
http://www.21stcenturysciencetech.com/Articles_2012/Biophoton_Revolution.pdf

[4] http://www.21stcenturysciencetech.com/Articles_2012/Biophoton_Revolution.pdf

[5] http://www.anatomyfacts.com/research/photonc.htm Since enzymes and anti-oxidants normally mop up reactive oxygen and free radicals before they can damage cells, healthy cells tend to release very few photons, making them hard to detect, even in a pitch-black lab.

[6] http://www.anatomyfacts.com/research/photonc.htm

[7] http://www.lifewave.com/pdf/AcuArticles/acuart-Anatomic-characterization.pdf
http://www.ratical.org/co-globalize/MaeWanHo/prague.pdf p. 14

[8] http://www.tohtech.ac.jp/~elecs/ca/kobayashilab_hp/NewScientist.html

[9] In quantum physics, coherence means that subatomic particles are linked by bands of common electromagnetic fields, so they can 'communicate'. As they get into phase, they begin acting like one giant wave.

[10] DNA may be an exciplex in which photons are stored. Non-coding DNA may act as a photon store and coherent radiator, because of its enormous polymer size and ability to form exciplexes. The resulting long range EM waves and fields can be seen as a basis of self organization.

[11] See The Field, p 45 f.

[12] *The Field,* Lynne Mc Taggart p. 39 f.

[13] http://www.lifescientists.de/

[14] http://nobelprize.org/nobel_prizes/lists/all/

[15] http://www.tohtech.ac.jp/~elecs/ca/kobayashilab_hp/NewScientist.html

[16] So far, the organ surface Bonghan Corpuscles (acupoint) in rats has been found to be relatively transparent.

[17] http://www.lifewave.com/pdf/AcuArticles/acuart-Anatomic-characterization.pdf . This is a reprint of the article *Anatomic characterization of acupuncture system and ultra-weak photon emission*
https://www.researchgate.net/figure/266456175_fig3_Figure-3-Optical-channel-model-of-biophotons-in-a-Bonghan-duct-DNAs-are-sources-of

[18] Imaging of biophoton emission from electrostimulated skin acupuncture point jg4: Effect of light enhancers 2008
http://nopr.niscair.res.in/bitstream/123456789/4469/1/IJEB%2046(5)%20340-344.pdf

[19] The two references are reported in the NIH funded study *Dialectrial Properties of the Skin*
http://www.bioelectromagnetics.org/bems2010/supp_data/P-B-152.pdf

H. Lazoura, M. Cohen, E. Lazoura, I. Cosic. *Do acupuncture points have different absorption properties to lazer light than surrounding skin?* 2nd International Conference on Bioelectromagnetism, Melbourne Au, 1998

C. Choi, K.S. Soh, S.M. Lee, G. Yoon. Study of propagation of light along an acupuncture meridian. Journal of the Optical Society of Korea 7(4): 244-7, 2003

[20] http://www.lifewave.com/pdf/AcuArticles/acuart-Anatomic-characterization.pdf p. 23

The book *Bioelectrodynamics and Biocommunication,* a collection of technical articles edited by Mae-Wan HO, Fritz-Albert Popp and Ulrich Warnke, draws the same conclusion, noting that in the 1990s a technique was developed to image live organisms by interference colors by detection of “dynamically ordered, coherent liquid-crystalline mesophases of the macromolecules making up living tissues. ….These measurements demonstrate that organisms are active dielectric, optical systems.

Bioelectrodynamics and Biocommunication edited by Mae-Wan HO, Fritz-Albert Popp and Ulrich Warnke World Scientific Pubishing 1994. ($349) p 431 f (referencing Chapter 8 of the book)
Google books

http://books.google.com/books?id=uxAfnxKMdPcC&pg=PA432&lpg=PA432&dq=SQUID+magnetometer+biophotons&source=bl&ots=6fni_oglSW&sig=RRKnWsVk3WJm_7mPCF91LaBnbog&hl=en&ei=8bTHTIeKEoX6swOXsbSnDQ&sa=X&oi=book_result&ct=result&resnum=4&ved=0CB4Q6AEwAw#v=onepage&q=SQUID%20magnetometer%20biophotons&f=false p. 432

chapter and author breakdown:
http://www.worldscibooks.com/lifesci/2267.html

see also: Imaging liquid crystalline mesophases in living organisms

"The authors now have a technique that optimizes the detection of small birefringences, enabling them to obtain high resolution and high contrast coloured images of entire, living, moving organisms. The technique depends on visualizing dynamically coherent liquid crystalline mesophases in the tissues. It involves viewing the organism between crossed polars with an asymmetrically placed compensatory full wave-plate-about 7.5° from either polarizer when brilliant colours are generated in all living tissues and organisms, whereas, little or no colour is generated when the wave-plate is at its usual position of 45° between the crossed polars. Another innovation in the authors' technique is that they can differentially illuminate various internal organs and tissues by adjusting the level of the condenser."
http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=369777 1994

[21] http://www.laserfocusworld.com/articles/print/volume-49/issue-02/world-news/photonic-crystals--liquid-crystal-control-improves-with-new-self.html

[22] The *Journal of Microscopy*, in an article titled *Nonlinear bio-photonic crystal effects revealed with multimodal nonlinear microscopy,* (http://onlinelibrary.wiley.com/doi/10.1046/j.1365-2818.2002.01081.x/full) by a Chinese team reports*: "*Highly optically active nonlinear bio-photonic crystalline and semicrystalline structures in living cells were studied by a novel multimodal nonlinear microscopy. Numerous biological structures, including stacked membranes and aligned protein structures are highly organized on a nanoscale and have been found to exhibit strong optical activities through second-harmonic generation (SHG) interactions, behaving similarly to man-made nonlinear photonic crystals." Photonic crystals are periodic optical nanostructures that are designed to affect the motion of photons in a similar way that periodicity of a semiconductor crystal affects the motion of electrons. Various forms of photonic crystals have been studied scientifically for the last 100 years

http://en.wikipedia.org/wiki/Photonic_crystal; tutorial on photonic crystals http://ab-initio.mit.edu/photons/tutorial/

[23] http://www.tohtech.ac.jp/~elecs/ca/kobayashilab_hp/NewScientist.html

[24] MIT: Technology Review
http://www.technologyreview.com/view/422069/the-puzzling-role-of-biophotons-in-the-brain/

[25] Humio Inaba, an engineer at the Research Institute of Electrical Communication at Tohoku University headed the project.

[26].

[27] http://www.tohtech.ac.jp/~elecs/ca/kobayashilab_hp/NewScientist.html

[28] . MIT: Technology Review
http://www.technologyreview.com/view/422069/the-puzzling-role-of-biophotons-in-the-brain/

There's certainly evidence that bacteria, plants and even kidney cells communicate in this way. Various groups have even shown that rats brains are literally alight thanks to the photons.

[29] http://www.technologyreview.com/view/422069/the-puzzling-role-of-biophotons-in-the-brain/

[30] http://en.wikipedia.org/wiki/Herbert_Fr%C3%B6hlich

[31] http://elizabethbauerconsults.com/motion.html

[32] http://en.wikipedia.org/wiki/Herbert_Fr%C3%B6hlich also see *The Intention Experiment* Lynne Mc Taggart p. 49 f
The following reference states the biological system could also take on the specific quantum property of non-locality:
http://nonlocal.com/hbar/frohlich.html

[33] The Hall effect is the development of a transverse electric field(Hall voltage) in a solid material when it carries an electric current and is placed in a magnetic field that is perpendicular to the current.
http://www.britannica.com/EBchecked/topic/252688/Hall-effect. The Hall effect is a rich source of information about the conduction properties of semiconductors.
http://Socrates.berkeley.edu/~phylabs/adv/ReprintsPDF/SHE%20Reprints/10-**Hall**%20**Effect**.PDF

[34] http://www.thefreelibrary.com/Energy+Medicine%3A+The+Scientific+Basis-a0163336257

[35] Biophoton Emission from the Hands Journal of the Korean Physical Society Vol 41 no. 2, August 2002, p 275-278
http://www.energetic-medicine.net/research/biphotonemissionfromthehands.pdf

[36] The article has no publication date, but references articles up to 2007, based on endnote dates

[37] Even MIT has now acknowledged "What's for sure is that biophotonics is one of the fastest moving and exciting fields in science today." http://trsub.com/blog/arxiv/26151 12/17/2010