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Biophoton – The language of the cells.
What can living systems tell us about interaction?

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Abstract

With the aid of new technologies, science has found creative ways to investigate nature. Through the use of a highly sensitive, low-noise, cooled camera, previously applied to exploring dark sky, scientific laboratories around the world have been looking at the weak emission of light from cells in a living organism. Biophoton emission, as so-called by Fritz Albert Popp, was introduced to science in the 1920's by the Russian embryologist Alexander Gurwitsh, receiving the name of "mitogenetic rays".

Since 1974, systematic research carried out by Fritz Albert Popp and his colleagues in many parts of the world has been focused on conducting experiments and working towards a biophoton theory to informs us about its properties. One of the main hypotheses is that biophoton plays an important biological function and due to evidence of coherence of its light, i.e., a high degree of order with an extremely stable intensity (Bischof, 2005), biophoton is supposed to operate as a biological laser, able to manage a network of information in the organism as well as to form electromagnetic field patterns.

Interactive art based on digital technologies uses numerical data to produce interactions between our body and lit pixels on the screen. Maybe, with the correct tools and equations, data from subtle fields of energy in living systems could be used to connect different systems of information, conjugating micro and macro levels of energy.
This paper intends to examine biophoton research as a possible model to interactive art and consider the way it could lead to new forms for perception and consciousness.

Keywords: biophoton, field, energy, interactive art.
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Biophoton, historical overview

In the 1920's Alexander Gurwitsh (1874-1954), a Russian embryologist, introduced the concept of a "morphogenetic field" to biology, strongly suggesting the existence of a coherent activity of embryonic cells regulated by optical interference (Beloussov and Popp, 1995). This hypothesis was motivated by his discovery of an ultra-weak photon emission from living systems, of which he gave the name "mitogenetic radiation", due to the suspected connections between this bioluminescence and cell division rate.

Alexander Gurwistch's experiment was performed using onion roots. He observed that cells division in the tip of one root influenced the division of cell in the other root, and, most importantly, that the communication between one root and the other only occurred if the medium used to isolate each root in the experiment was a quartz glass[1]. Using an ordinary glass, such influence was blocked. Thus, he concluded this phenomenon must be a "mitogenetic radiation" in the UV range (Bischof, 2005). Alexander Gurwistch was

[1] Details about this experiment and the history of Alexander Gurwitsch can be read in English in LIPKIND, M. A. & BELOUSSOV, L. V. (1995), *Alexander Gurwitsch: Personality and Scientific Heritage*. IN BELOUSSOV, L. V. & POPP, F.-A. (Eds.), *Biophotonics : non-equilibrium and coherent systems in biology, biophysics and biotechnology. Proccedings of International Conference dedicated to the 120th birthday of Alexander Gavrilovich Gurwitsch (1874-1954).*

convinced at that time that the life process was somehow entangled in a "morphogenetic field", manifesting in a form of "mitogenetic radiation"[2].

Alexander Gurwitsh was ahead of his time, however, for the second decade of the 20th century there was not adequate technological apparatuses to support the physical experiments necessary to the development of his theories. It was only after the Second World War, with the aid of newly developed photomultipliers[3], that the observation of very weak photon emissions in the spectral range from 400-700nm was possible (Mei, 1994). With the aid of such technology, in the 1970's the assistant professor Fritz-Albert Popp, at the University Marburg was successful in showing evidence of ultra-weak photon emission from living tissues, being the first to call it phenomenon biophotons.

What are biophotons?

Photon comes from the Greek word "ph□s", meaning light. In quantum physics it is the term used to designate a quantum of electromagnetic radiation. In turn, biophoton refers to photons emitted by biological systems. Though in order to understand biophotonic research clearly, certain concepts must be defined. The emission of photons by living systems is very well established in the scientific community. It can be observed, for instance, in the area of bioluminescence research based on luciferin-luciferase reactions. However, researchers of biophotons claim that "low intensity photon emission between 200nm and 800nm detected with a photon counting device, has been found in almost every species of biological tissues examined" (Ibid., 1994). The light given off by the organism, in the sense of biophoton emission, is not caused by "chlorophyll, thermal influence, 'spontaneous chemiluminescence', or some other 'contamination effect' (Bischof, 2005) as it was once thought.

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[2] Is important to say that there are some controversy remaining about the fact the dividing cells emit UV light despite the efforts of several groups across the world and the review report by Quickenden *et al.* (DEVARAJ, B., USA, M. & INABA, H. (1997), Biophotons: ultraweak light emission from living systems. *Current Opinion in Solid State and Materials Science,* 2**,** 188-193.)

[3] Photomultipliers are extremely sensitive devices able to detect photon emission or very weak light in the ultraviolet, visible and near infrared range. In these detectors the signal produced by the incoming light is multiplied by as much as 10^8.

Masaki Kobayashi, physicist at the Tohoku Institute of Technology in Sendai, has defined biophoton as "a spontaneous photon emission, without any external photo-excitation, through chemical excitation of the internal biochemical processes underlying cellular metabolism. Biophoton emission, originates in the chemical excitation of molecules undergoing oxidative metabolism. It is distinct from thermal radiation arising from body temperature. (…) Biophoton phenomenon has been surveyed from cellular or subcellular levels up to individual organism level, following the development of the highly sensitive photon detection techniques"[4].

The work of Fritz-Albert Popp and several scientific groups in Austria, Brazil, Chile, China, India, Italy, Japan, Poland, Russia, Switzerland, Southern Korea and USA, has brought considerable evidence that biophoton emission must be associated with biological and physiological functions, showing that biophotons are highly sensitive to environmental changes and behaves as a result of physiological process and also acts as its regulator, and finally, confirming non-thermal character of this "low level luminescence" as well as its high degree of coherence[5] (Popp et al., 1984; Mei, 1994; Devaraj et al., 1997).

According to Marco Bischof, author of *Biophotonen - Das Licht, das unsere Zellen steuert*[6] an extensive book about biophotons, "this radiation is very, very weak, but it is not like an ordinary light, because it is coherent. Like laser light. Coherence is, when you have two waves and they go in steps, in the same phase. But the interesting thing is that this light is much more coherent than any laser that is possible to make." (Bischof, 2006).

Coherence, synergy and the field

[4] KOBAYASHI, M. *Biophoton*. Available at: http://www.tohtech.ac.jp/~elecs/ca/kobayashilab_hp/BiophotonE.html Accessed on: 02/06/2006.
[5] *Biophotons and Biophotonics: definitions.* Available at: http://www.lifescientists.de/. Accessed on: 11/03/2006.
[6] Summary of contents in English at http://www.marcobischof.com

In the quantum world coherence means that subatomic particles are in a coordinated state. Technically it refers to the condition of subatomic waves, or particles, being in the same phase. In the case of biophotons the idea of coherence was first introduced by Fritz-Albert Popp (Popp, 1979). Coherence overlaps with the concept of synergy in the sense of cooperation. Coherence means that the photon particles or waves released by the cells form a whole interlinked system working as a synchronic electromagnetic field. The high degree of order in such light reflects its laser-like properties.

Bischof states that "such light is very quiet and shows an extremely stable intensity, without the fluctuations normally observed in light. Because of their stable field strength, its waves can superimpose, and by virtue of this, interference effects become possible that do not occur in ordinary light. Because of high degree of order, the biological laser light is able to generate and keep order and to transmit information in the organism." (Bischof, 2005)

In her book The Field, Lynne McTaggart (2001), an American journalist, makes an analogy that helps us to understand the concept of coherence in biophotons. Comparing this phenomenon with an orchestra, she proposes that each photon is playing a single instrument, imperceptible as a single unit. However, what results from that process is a harmonic symphony due to the synchronicity of its inseparable parts. "They are like a multitude of tuning forks that all begin resonating together."

In biophoton research,"induced emission" is the method used to observe evidence of the coherence state of light. It is a type of measurement where the organic sample is exposed to a flash of light which induces it to emit a photon signal of characteristic shape, "delayed luminescence". Through analysis of such a signal, graphically displayed in the form of a hyperbolic curve, there has been evidence of the nature of coherence in biophoton emission. According to Bajpai, the fact that the decay character of the biophoton luminescence is not exponential is suggestive of its coherent state.

The results of intensive measurements, via method of induced delayed luminescence, have suggested that "the coherent nature of biophotons requires a quantum description of the biophoton field; which is presented in the form of a model. The model assumes that an electromagnetic field exists around a living system; the field is specific to the system and is in a squeezed state of photons." (Bajpai, 1998; Bajpai, 1999).

Coherence seems to play a fundamental role in the biological functions of the organism. Based on several researches in the biophotonic field, it is supposed that the interchanges between coherent and incoherent states of biophotons emissions are the basis of a biological process by which the body regulates itself on many levels. Despite the fact that, so far, the origin and purpose of the coherent luminescence observed in biophotons emissions are not known, researchers of biophoton argue that it must be evidence of a communicational network system acting through a resonant field of interactions.

Biophoton theory suggests light is stored in DNA (Popp et al., 1984), more precisely at the cell's nuclei. This was observed when the ultra-weak photoemission stopped appearing after removal of the cell nuclei. According to Fritz-Albert Popp, DNA works as an "exciplex/excimer laser system". It collects photons and emits then as coherent light. Technically speaking, coherent states of light originate in the DNA as a product of interactions between electromagnetic waves and mechanical base oscillations between photons and phonons in the DNA molecular skeleton (Mei, 1994). In a simple world we could say that the DNA works as a tuning fork vibrating in resonance with a field of electromagnetic waves in a cooperative synergetic phenomenon.

Interacting with the source

An alternative but effective method of research in biophoton is based on the use of a highly sensitive, low-noise, cooled CCD[7] camera, normally used in astrophysics. In a light-tight chamber, plant, seeds and even part of the human body are exposed to this

[7] charge-coupled device

device in order to capture images and data from biophotons emissions. Katherine Creath, from the Department of Optical Sciences and Medicine College of Optical Sciences, University of Arizona, has been working on images of leaves over the past two years. After the study of thousands of images recorded along with this process, Katherine Creath began to observe "halo-like" patterns surrounding the plant parts. When the leaves are in close proximity the pattern between the plants appear stronger than usual. It is observed, for instance, in the geranium leaves put inside a light-tight chamber for two-hour exposure. According to Creath, "when the plant is placed in darkness, the chlorophyll fluoresces for few minutes. After this fluorescent decays, biophoton emission persists as a by-product of metabolic function" (Creath and Schwartz, 2005).

Considering the published studies in biophoton one could argue that this radiation, visible through the camera, indicates some kind of interaction between the leaves, that it would be part of the regulatory process of biochemical functions within and between cells, evidence of some sort of network accountable for intracellular, intercellular and, maybe even, organism-environment communication.

Actually, subtle interactions between plants and humans have been investigated with the assistance of biophoton imaging. Melinda H. Connor, from the Program in Integrative Medicine at University of Arizona utilizes a Roeper Scientific Biophoton Imaging System to aid in determining baseline characteristics of healing in energy practitioners. The method consists in submitting geranium leaves, under matching light conditions, to the master energy practitioner. The practitioner was asked to "run energy", using their hands, to have the leaf either "heal" (reduce emission) or glow (increase emission). The practitioner continued in this way for 10 minutes in each trial. After this stage the leaves were put in the light-tight chamber for post-experiment measurements. The results observed through visual and data analysis of the images demonstrate evidence of changes in biophoton.

Reflecting upon results of biophotons research in plants and healers, we might assume some basic hypotheses: 1) existence of correlations between human intention

(consciousness) and biophoton emission; 2) biophotonic states from different organisms may interact with each other by means of a subtle field; 3) the pixel light in the biophoton imaging can be explored as a visual interface for interactive communication.

How biophoton interacts with art

First of all, I would like to call attention to what is implicit in the realm of biophoton research. There are two schools of interpretation of biophoton phenomenon (Bischof, 2005). The first one attributes the process of photon emissions by living organisms to "physical and chemical principles of luminescence of biological molecules" and "chemical reactions and radical reactions and oxidation" without any biological function. On the other hand, the second school, in line with Popp's research and understanding of biophoton, despite the fact they don't deny the occurrence of biochemical processes in the basis of this phenomenon, in contrast with a classical molecular view of the biochemical school, they interpret the organism as a macro quantum system that cannot be reduced nor interpreted by the analysis of their single particles, but rather can be pictured by they holistic field aspect.

The concept of an integrative biophysics founded on quantum mechanics assumes a non-reductionistic view of the organism. It is not based on or restricted to an atomistic-molecular description of their behaviour or functions. Instead, it includes, in the understanding of living system's behaviour, "the insight into the fundamental interconnectedness *within* the organism as well as *between* organisms, and that of the organism *with the environment*" (Bischof, 2003).

Such ontological approach to the organism offers to techno-art research and life a new framework for interactive models. Since the artist and the viewer are both organic instances of a broader system of dynamic information, changes in the way living systems are interpreted, analyzed, perceived, will, in turn, affect one's perception over the whole environment.

At fist glance, two arenas of artistic and scientific investigation are opened up. The first one demands operation straight at molecular level, considering the DNA, in accordance with biophotonic research, as a source of extra information embedded in holographically coded form (Bischof, 1996). According to Scott Hagan, a theoretical physicist at the British Columbia Institute of Technology in Burnaby and Stuart Hameroff, associate director of the Center for Consciousness Studies at the University of Arizona, quantum coherent states, derived from biophoton processes, might be somehow linked to the control basis of rising consciousness (Daviss, 2002). Data analysis of biophoton imaging, as well as information collected from photomultipliers might provide a considerable source of variables for development of interactive interfaces. Such operation could lead to new enquiries in the realm of consciousness research, as well as to new perceptual aspects of an interactive field. In that sense, crossing fields of different scales, i.e. nano field with macro field (environment), may lead to the emergence of new models of perception and consciousness. Roy Ascott suggests:

> "The whole body must be considered in a state of quantum coherence, with each molecule interacting with each other within a field. Just as the field has a regulatory effect on molecules, so molecules give the field boundaries. What then happens when a Mixed Reality environment, by merging virtual and biological systems and amplifying their interdependency, extends this boundary and redefines the field? Mixed Reality, networked reality and telematic virtuality, I would suggest, become entangled with the quantum states of coherence, leading to the emergence of universal connectivity and nonlinear relationships that exist beyond the classical constraints of space and time." (Ascott, 2006)

The second area of art investigation, related to biophoton phenomenon, would be the application of field thinking as a conceptual model to interactive art. In physics, field may be defined as a function of space and time. "In biology, the field is a concept which describes a biological system, the behaviour of whose parts is determined by positions of the parts in the system" (…) "the field is essentially a messenger, a link. It uses space-time as a language to 'mark' continuous interaction between matter" (Wolkowski, 1995).

From a western point of view, emptiness is the space between objects. Beginner art students use to think about emptiness as the area left free from drawing process, the space not worked, which is supposed to be filled up with new strokes to get the work finished. Skilled artists understand the importance of the emptiness as a negative space, complementary to the whole image. They are aware of what, for the Eastern culture, is a tradition: emptiness is form.

Modern quantum physics has brought new light to Western vision of emptiness. The introduction of quantum field theories promotes inseparability between filled and emptiness, field and matter. They are both part of the same indivisible body. Field is the only reality (Čapek, 1961 apud; Capra, 1976).

In the realm of techno-art, the physical space, cyberspace and imaginary space are entangled. The flux of informational networks may be thought as structural lines of an invisible field interconnecting elementary parts. Sensors, interfaces, organic and artificial bodies are physical and virtual nodes resonating in response to the system's dynamics. From this concept, we might propose that form emerges as a result of transference of energy, or more precisely, information, non-localized, distributed in the whole system. Form as a result of a communicational process.

Conclusion

Biophoton research brings to the theoretical and practical arena of techno-art a vision of the organism in terms of field. It reveals an extra dimension of the living system that surpasses their physical aspect. The idea that a mechanical and limited body may be obsolete doesn't make sense when we consider living systems in such level of complexity and intelligence. But the core contribution of biophoton research is providing evidence of coherence in living systems, embodying this phenomenon in biology. The coherent state observed in biophoton phenomenon opens up space for an understanding of the organism

in terms of resonance, synchronization, interferences, harmony and compatibility. Coherence is a pre-requisite for life and "universal communication" (Ho and Popp, 1989)

Light seems to play a central role in life and communication. It comes naturally from the sun, its fundamental source, to be absorbed and redistributed along with the ecological and technological web. Delayed luminescence, in that sense, contributes to this bidirectional aspect of the light network. Through biophoton research, living systems can be interpreted by their capacity "to build up and extend coherent spatio-temporal platform for communication" (Ibid., 1989). It reinforces the idea of evolution based on coherence, synergy, and communication.

In previous decades technology has considerably improved our capacity to communicate. In fact, the idea of field in techno-art rises from the perception of the informational space boosted by digital technology. Biophoton research opens a window to observe the body expression in terms of photon and waves, light and field. I make Stephen Wilson's words my words: "artists can serve a useful function by being aware of the full range off research that may be culturally significant in the future" (Wilson, 2003), and finish this paper wondering if, one day, the same way we look at the sky, make a wish on a shooting star, we could imagine the dance of lights inside our body as a source of inspiration and beauty for life.

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