Integrative Biophysics: Biophotonics: F.A. Popp et al Springer, 2003

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published dec 2010 ????

- **Cover Type:** Paperback with 512 pages
- **Published by:** Springer
- **Edition:** 1st Edition. edition November 2, 2010
- **Written in:** English

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Integrative biophysics: biophotonics

Edited By Fritz Albert Popp, L. V. Belousov
Kluwer Academic Publishers
Springer 2003 ($215)

Call for a new approach to biophysics.
Molecular biology has dominated biophysics since 1930s

Biophotonics is a rapidly increasing field of current scientific research and applications, based on the discovery of biophotons, a permanent, weak photon current emanating from all living systems. The biophoton emission reflects some, if not all, of the essential biological and physiological activities in biological systems. Biophotonics provides a powerful tool for investigating these electromagnetic interactions. The theoretical approach requires holistic models of living systems, rather than local analytical models. Consequently, these new insights into living matter create a new basis of "integrative biophysics" that is concerned with the questions of regulation, communication and organization of biological systems.

Most of the specialists working in this interdisciplinary field of physics, biology, biophysics and medicine are associated with "The International Institute of Biophysics" (IIB), in Neuss, Germany, where basic research and possibilities for applications are coordinated. The growth in this field is indicated by the increase in financial support, interest from the scientific community and frequency of publications.

Audience: The scientists of IIB have presented the most essential background and applications of biophotonics in these lecture notes in biophysics, based on the summer school lectures by this group. This book is devoted to questions of elementary biophysics, as well as current developments and applications. It will be of interest to graduate and postgraduate students, life scientists, and the responsible officials of industries and governments looking for non-invasive methods of investigating biological tissues.
http://www.springer.com/physics/complexity/book/978-1-4020-1139-9

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Chapter 12: Biophotons- Background, Experimental Results, Theoretical Approach and Applications FA Popp

Popp does not mention molecules very often; he talks about biophoton interference

- The spectral intensity $i(\nu)$ never displays small peaks around definite frequencies ν. Rather, the quite flat spectral distribution has to be assigned to a non-equilibrium system whose excitation temperature $\vartheta(\nu)$ increases linearly with the frequency ν. This means that the occupation probability $f(\nu)$ of the responsible excited states does not follow a Boltzmann distribution $f(\nu) = \exp(-h\nu/kT)$ but the rule $f(\nu)$ = constant (Fig.3).

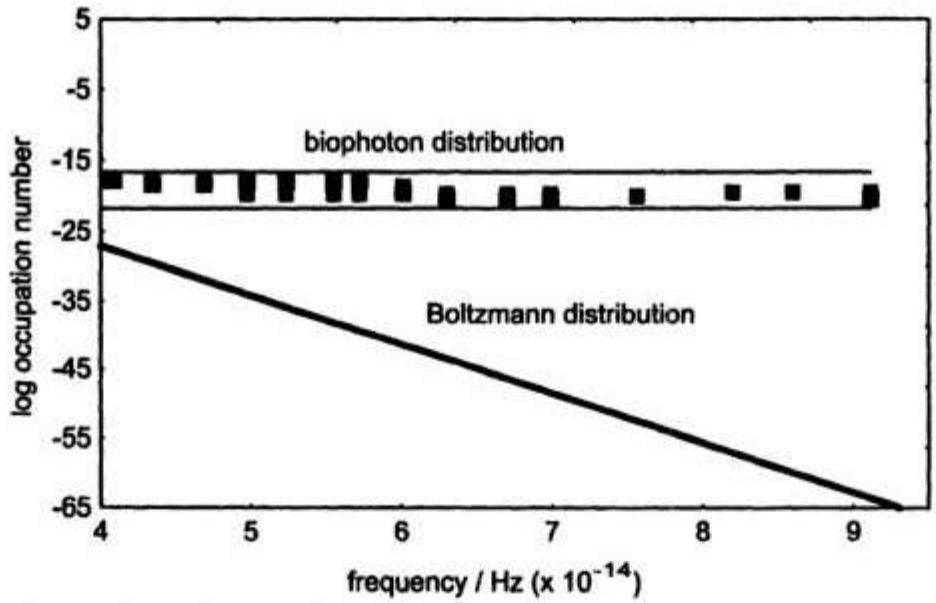

Figure 3: In the case of average occupation numbers we obtain an f = const.-distribution that with increasing frequency displays increasing deviation from the Boltzmann-distribution.

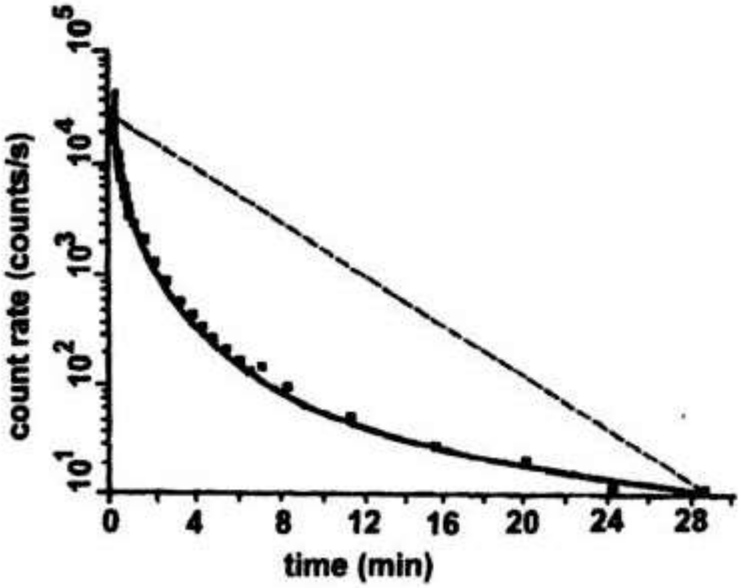

Figure 5: Instead of an exponential decay (dashed line), living cell populations (here tissue of Bryophyllum daigremontanum) exhibit a hyperbolic relaxation of photon intensity after exposure to white-light-illumination. This holds for total as well as for spectral observation (here at 676 ± 10 nm). Under ergodic conditions, hyperbolic decay is a sufficient condition of perfect coherence.

equilibrium conditions. The next step is the reduction of N by mode coupling. For $N \rightarrow 1$, entropy may approach even 0 without violating the maximum entropy principle.

In order to stabilize $f(\nu)$ = constant and quantum coherence, suitable matter has to be inserted to fix the boundary conditions. Thus, the f = const. rule can be established by polymers where the distance between the molecular units has to be much smaller than the wavelength of light and where Casimir forces are relevant. It is likely that this role is taken by the DNA. On the other hand, the reduction of degrees of freedom provides some Bose-condensation-like process. Actually, the living cell may have developed to just the degree of coherence of the biophoton field where Bose-condensation and thermal dissipation balance each other [20]. This provides a relatively broad zone of "homeostatic" feedback coupling between matter and radiation, explaining qualitatively "delayed luminescence" and the necessity for permanent biophoton emission and quantitatively the temperature dependence of biophoton emission.

From the more "classical" point of view, this development from low (classical) to higher and higher orders of quantum coherence by spreading out the position- and momentum space corresponds to the expansion of coherent states in terms of more and more efficient storage of external light (and other electromagnetic waves). Consequently, one expects that biological structures are based on cavity resonators and wave guides. Fig.8 displays a striking example. Actually, the whole of mitotic activity can be described in terms of superpositions of cavity resonator waves, which represent at the same time examples of coherent states of the biophoton field.

The living cell may have developed to the degree of coherence of the biophoton field where Bose-condensation [pure coherence] and thermal dissipation balance one another. This explains delayed luminescence.

With higher orders of quantum coherence, one expects that biological structures would be based on cavity resonators and wave guides. Miotic activity can be described in terms of superpositions of cavity resonator waves, which also represent coherent states of the biophoton field.
P. 396

Figure 8: Left side. Completely developed spindle apparatus of a fish (Corregonus) in mitosis. (From: Darlington, C.D., Lacour, L.F.: The Handling of Chromosomes. Allen and Unwin, London, 1960).
Right side. Electric field of TM_{11} cavity modes in a right circular cylindrical cavity. Comparison with Fig.8 left side shows that mitotic figures are striking examples of long-lasting photon storage and coherent fields within biological systems (From: Popp, F.A.: Photon Storage in Biological Systems, In: Electromagnetic Bio-Information, Urban & Schwarzenberg, Muenchen-Wien-Baltimore 1979).

At present we may formulate the role of biophotons in a picture rather than by means of a quantitative theory. Biophotons originate from a coherent field which keeps its coherence through an unknown "homeostatic" coupling between radiation and matter. The electromagnetic field pattern is the driving force for the movement and interaction of the molecules (including the spatio-temporal regulation of biochemical reactivity by suitable excitation of transition state complexes), while matter constitutes the boundary conditions of the field. Field and matter in biological systems are somehow "married" in a way that they control each other by mutual coupling of dynamical interference patterns of the field with the rather flexible material boundaries.

Biophotons originate from a coherent field which keeps is coherence thru some type of coupling between radiation and matter. The electromagnetic field pattern is the driving force for the movement and interaction of molecules, while matter constitutes the boundary conditions of the field. P. 397.

A striking example is the measurements on daphnia [32, 33]. *Daphnia magna* Strauss were put in darkness into water at 18 ^{0}C within the quartz cuvette of the biophoton measuring equipment. We altered the numbers n of daphnia from 1 to 250, always selecting animals of about equal size. After each alteration the intensity of the biophoton emission was registered. Since every one of the inbred animals emits almost the same intensity, one expects a dependence of biophoton intensity on the number of animals like that displayed in Fig.10a. After correction for self absorption, it should not significantly deviate from that of Fig.10a. However, careful measurements showed evidence of the results displayed in Fig.10b. The results from interference patterns of biophotons between the animals under investigation were as expected. There is a tendency for destructive interference resulting in a lower intensity than expected from the linear increase. The most efficient destruction of the biophoton field outside of the animals is obtained at about 110 animals, corresponding to the population density of daphnia in free nature. This zone of most efficient destruction according to the energy conservation law is at the same time the zone of highest efficacy in "storing" light *within* the animals.

By Fritz Albert Popp, L. V. Belousov

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0 5 10 20 30 40·10⁻⁷/ml

Figure 12: The decay parameter of the hyperbolic approximation that is adjusted to the relaxation dynamics of the afterglow of different cell suspensions after exposure to weak white light illumination is shown versus cell density. The lower curve displays the improvement of hyperbolic relaxation of normal amnion cells with increasing cell density. The upper curve shows the opposite dependence exhibited by malignant Wish cells. The three measurements at the right side of the figure correspond to the nutritive medium alone.

To some extent one is justified in saying that living systems "suck" the light away in order to establish the most sensitive platform of communication. A more detailed description of this phenomenon has been presented elsewhere [29]. Actually, this biocommunication by means of mutual interference of the biophoton field provides necessary information about the equality or difference of species, since similar animals have similar wave patterns. The signal/noise ratio becomes optimized as soon as the wave patterns interfere under maximum destruction between the communicating systems, since every perturbation leads then to an increase (signal) that the connected systems have to become aware of.

This rather ingenious means of biocommunication provides the basis for orientation, swarming, formation, growth, differentiation, and

Biocommunication by means of mutual interference of the biophoton field provides information about the equality or difference of species.

Chapter 13: The physical basis of life RP Bajpai p. 439

Quantum effects without classical counterparts include: holistic behavior, superposition of all possible paths, phase of wave functions, non-locality, entanglement, and quantum selection. P. 442

Molecular biology fails to account for consciousness. In order to account for consciousness, the framework of molecular biology needs to be quantum theory. The inclusion of a quantum framework can be done in a way that retains the successes of molecular biology.

In addition to the quantum states of biomolecules, a number of quantum states of a living system are not specifiable by biomolecules; these additional states re responsible for holistic properties. A living system in these states will function as a macroscopic quantum object. The framework of quantum theory does not ascribe special significance to time. It

is suspected that time enters through the transfer and processing of information. The speed of information processing has to be much faster in consciousness properties than in macroscopic properties. P. 444

A physical devise acting like a Maxwell's demon can create structures in a system and perform regulatory functions by extracting energy from a source other than the system later. The devise merely acts as a catalyst and can continue to function perpetually. Many protein molecules form structures and perform regulatory functions by acting like Maxwell demons. P. 449

Heat energy is described as a mixed state with random phases in the quantum framework while energy in a pure quantum state has a well defined phase. P 450

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The electromagnetic nature of reactions involving biomolecules causes the energy to flow as a photon or an EM signal. The properties of an EM signal in a pure state are different from the properties of a signal in a mixed state.