BIOPHOTONS – THE LIGHT IN OUR CELLS

By Marco Bischof

Light is not only what brightens up our world by day and makes us see the things around us, light is also produced by our own cells and forms a major component of man's inner environment and a non-material part of our bodies connecting us with the outer environment. The existence of this endogenous light has been discovered in the 1920's by the Russian embryologist Alexander Gurwitsch and has been conclusively demonstrated by modern biophysicists since the late 1960's with state-of-the-art technology and methods.

All living organisms, including humans, emit a low-intensity glow that cannot be seen by the naked eye, but can be measured by photomultipliers that amplify the weak signals several million times and enable the researchers to register it in the form of a diagram. As long as they live, cells and whole organisms give off a pulsating glow with a mean intensity of several up to a few ten thousand photons per second and square centimeter. This corresponds to a candle-light seen from 15 miles distance and is tens to hundreds of millions times weaker than daylight. This glow can also be made visible by means of a CCD camera whose input of differences in brightness is then transformed by a computer into colors displayed on a video screen. Because of its low intensity, this cellular glow, also known as biophoton emission, is often referred to as ultra-weak cell radiation, or ultra-weak bioluminescence. Its spectral range of frequencies (colors) extends from 200-800 nanometers, i.e., from UV-C and UV-A through the whole visible range into the infrared part of the spectrum. It should not be confounded with the „bioluminescence" of fire-flies, glow-worms, deep sea fishes, and rotting wood which is much stronger, has different properties, and is clearly of chemical origin.

Historical development of biophoton research

Biophotons were discovered in 1922, when the Russian embryologist and histologist Alexander G.Gurwitsch (1874-1954) performed an experiment with onion roots. He found that some influence from the dividing cells at the tip of one root stimulated the division of cells in the other root. When he observed that this influence passed through quartz glass, while it was blocked by ordinary glass, he concluded it must be a „mitogenetic radiation" in the UV range. Gurwitsch was convinced that this radiation was an expression of „morphogenetic fields" within the organism that structured and organized the life processes in the cell and the organism. However, with the technical means available from the 1920's to the 1940's, Gurwitsch and his collaborators at the Leningrad Research Institute for Experimental Medicine and at the Academy of Medical Sciences in Moscow were not able to reliably measure mitogenetic radiation. They mainly used „biological detectors" such as the onion root just mentioned, or yeast cultures, to register the radiation. Only when after World War II photomultipliers became available to biomedical researchers, measurements proved the existence of cell radiation beyond doubt. They were able to detect a hundred times weaker photon streams and could even register single photons.

In the West, this happened first in 1954-55 when the Italian biophysicists L.Colli and U.Facchini and their collaborators at the University of Milan verified Gurwitsch's discoveries with the new technology and showed that sprouts of various plants emit visible light. However, after their two publications they did not continue the investigations. In the 1960's the first reports by Russian scientists about „ultraweak cell radiation", as mitogenetic radiation was now called, were published in Western languages. While Russian scientists had done extensive investigations with photomultipliers since the late 1940's, systematic Western research in this field only started with the experiments of the Australian physical chemist Terence I.Quickenden in the late 1960 and early 1970's, and finally with the work of the German biophysicist Fritz Albert Popp from 1974 onwards. Popp and his collaborators at the University of Marburg, and later at the University of Kaiserslautern and the International Institute of Biophysics at Kaiserslautern and Neuss, were the first to carry out systematic experimental and theoretical investigations of all questions related to this new biological phenomenon.

In the 30 years since then, Popp and his colleagues – and many other researchers all over the world – have not only demonstrated the existence and ubiquity of biophoton emission beyond any reasonable doubt, but also have established its properties, have developed and tested a number of hypotheses about its possible biological functions for which much evidence has been found, have done a lot of theoretical work towards a biophoton theory explaining all or some of the phenomena observed, and have started to develop a number of practical applications for the use of biophoton measurements of microorganisms, plants, animals, and humans. Today, the International Institute of Biophysics (IIB) founded by Popp and some of his colleagues in 1996 has become an international research network comprising 22 members of 14 research groups at universities in the USA, China, Russia, Poland, India, Japan, Korea, Israel, Italy, England, and Germany. Altogether, there are about 40 research groups worldwide working in biophoton research.

The properties of biophoton emission

After having shown that biophoton emission is a general property of all plant and animal life, Popp's team set themselves the task to show that the glow organisms gave off was not just caused by chlorophyll, thermal influence,„spontaneous chemiluminescence", or some other „contamination effect". In the 1970's, the American biochemist H.H.Seliger and the Russian biophysicist A.I.Zhuravlev had postulated that bioluminescence originated from occasional losses of the excitation energy that usually is used up in chemical processes, and therefore had no biological significance whatsoever. Today we know from the work of Popp's group and that of other scientists that biophoton emission correlates strongly with all the life activities of the organism by which it is emitted, and therefore very probably fulfills some biological function(s). Unlike chemical bioluminescence, before the death of an organism its intensity increases steeply more than a hundred- or a thousandfold, and then decreases down to zero at the moment of death. The radiation also increases during mitosis (cell division) and undergoes very characteristic changes during all phases of the cell cycle. It reacts very sensitively to all disturbances, external influences, and inner changes in the organism. For this reason, its measurement can be used as a reliable and sensitive indicator for such influences and changes.

The coherence of biophotons

The most convincing argument against the „degradation theory" of Seliger and Zhuravlev however is the evidence for the coherence of biophotons that Popp and his team have provided in the course of the last twenty years. Biophotons consist of light with a high degree of order, in other words, biological laser light. Such a 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 the high degree of order, the biological laser light is able to generate and keep order and to transmit information in the organism.

In biophoton research, the property of coherence mainly shows in the „hyperbolic decay" of so-called „induced emission". Two types of measurement are used in biophoton research. In the „spontaneous emission" of a sample it is practically impossible to provide evidence of coherence. For this reason the measurement of „induced emission" has become an important instrument of biophoton research, where it is possible to determine the degree of coherence of the light emitted by the organism. Here the sample is illuminated by a short flash of light, before the researcher measures in which way the absorbed light is given off again. In doing so, he can observe that biophoton emission from living tissue shows a very extended decaying process lasting for a period of minutes to hours – something which is never observed in dead objects. Furthermore, this decay continuously slows down, such that the decay curve becomes flatter all the time and the emission never really ceases. Popp has given proof that such a decaying behaviour – which graphically is displayed in the form of a hyperbolic curve – is evidence of the coherence of the measured emission and indicates that light is stored in the tissue. Another conclusion that can be drawn from this behaviour of the re-emitted biophotons is that the emission is not originating from isolated molecules in the cells, but that the emitting molecules are coupled by a connecting coherent radiation field. A central role in the light storage seems to be attributable to the DNA in the cell nucleus which Popp's group has shown to be the main light source in the cell.

Two schools of interpretation

Today the majority of scientists working on ultraweak cell radiation still subscribes to Seliger's and Zhuravlev's biochemical view. They base their understanding on the well known physical and chemical principles of the luminescence of biological molecules and attribute the light emission to certain chemical reactions such as radical reactions and oxidation. They consider the light emission from organisms to be a mere waste product of metabolism without any biological function. Nevertheless they have developed its measurement into a useful instrument for detecting oxidative damage in organic materials, such as the rancidity of oils and fats.

Popp and his group, on the other hand, have developed another, biophysical interpretation of the phenomena based on a new understanding of life derived from quantum optics, non-equilibrium thermodynamics, and other recent developments in science, which today is accepted by a growing minority of the researchers in the field. They do not deny that radical reactions and other biochemical processes occur and may generate some of the light emitted by organisms, but see biophoton emission mainly as the expression of an overall regulating field in the organism in which also such chemiluminescent events are embedded. In contrast to the classical, molecular view of the biochemical school, they describe the organism as a macroscopic quantum system in which not the particle aspect, but the holistic field aspect predominates. They assume that all the molecules of the organism are coupled to each other by a coherent radiation field in such a way that they form a unity in which biophotons cannot be assigned any more to any particular emitters, but must be considered to be emitted by the organism as a whole.

The analysis of biophoton measurements has shown that the emitting matter forms a biological laser mechanism, which at the same time is an experimental confirmation of the view that the organism is an open system far from thermodynamic equilibrium. This coherent biophoton field which permeates and envelopes the solid body is assumed to regulate and control all the life processes in the organism. It is a holographic field of standing waves which is able, through a broad spectrum of frequencies and polarisations and in close interplay with all material structures, to transmit signals with the speed of light to any place in the organism and to activate or to inhibit biochemical processes, to organize matter, and much more. The material structures involved in this are predestined to function as antennae for the absorption and the emission of these signals, because they possess, by virtue of their evolution in the terrestrial radiation field and their coevolution with the biophoton field, precisely matching geometries and dimensions.

The biological laser field of the organism stabilizes exactly at the „laser threshold" where it can oscillate between the coherent mode of operation and the incoherent mode of operation, and thus combine the advantages of both regimes. This threshold is a „non-equilibrium phase transition" (or „dissipative structure") where the light can spontaneously and abruptly change its order. Above the laser threshold, in the coherent regime, the photon field switches over into a stable and highly ordered interference pattern in which the waves superimpose coherently. The various light sources assume a coordinated behaviour and function like a whole. At the same time these waves are amplified autocatalytically and turn into laser light. Below the threshold, in the chaotic regime, the light sources decouple and function separately. There is still coherent superimposition of waves, but it is dominated by the absorption of light. Both regimes are necessary for the organism; for some purposes independently functioning elements are needed, for others, coordinated behaviour is more advantageous. According to Popp, this is the mechanism by which the organism regulates itself on all levels.

This hypothetical mechanism is based on the assumption that the laser mechanism of biological systems operates not only with the low-grade coherence known from technical optics, but uses the ideal quantum-optical coherence defined by Harvard physicist Roy J.Glauber around 1970. Popp believes the quantum field of living systems realizes the form of a „coherent state", a paradoxical state with minimal quantum uncertainty that unites the properties of wave and particle, coherence and incoherence, localisation and delocalisation. All the evidence of biophoton research so far suggests that biological systems realize a form of optimal coherence that science has yet to fully understand. The measurements show evidence for the existence in biological systems of a new class of quantum phenomena recently investigated by a number of very advanced disciplines of quantum optics and electrodynamics, such as Non-Classical Light and Cavity Quantum Electrodynamics. Two of the properties identified by these new disciplines that are realised in organisms are the coherence of mixtures of wavelengths (non-monochromatic light) and the occurrence of coherence in very weak light. Recently, the Popp team has demonstrated that biophotons indeed exist in the form of such non-classical light, or more specifically, so-called „squeezed states" which are a particular form of coherent states (Popp et al., 2002).

Biophoton measurements on humans

The emission of biophotons has not only been established for practically all plant and animal organisms. Although only a few such investigations have been realized up to now, we now know that weak, but highly coherent light is also emitted by the human body. While some earlier measurements of human biophoton emission have been made in the Soviet Union, the first Western investigations were carried out by the New York team of Richard Dobrin and John Pierrakos in the late 1970`s. They found emissions of some hundred photons per second from the chest in the UV and visible range of the spectrum. Some test persons were able to increase the emission up to 100 percent by using breathing techniques and deliberate tremblings. In 1989 and 1990, a group of British researchers obtained more than three times higher intensities in the spectral range of 420-650 nm from hands, trunk and forehead. The palms showed a much higher emission (500 photons per second) than trunk and forehead. The emission at the particular regions of the body remained quite regular, but the team found indications for temporal variations with a maximum in the evening. In the 1990's, systematic long-term investigations of human biophoton emission with a specially developed whole-body biophoton-counting equipment were started in Popp's lab, mainly conducted by Sophie Cohen (Cohen & Popp, 1997, 1998; Cohen, Popp & Yan, 2003). The most interesting results were the findings on the rhythmicity of the emission, the significance of right-left asymmetries, and the non-local effects of treatments on the emission. Long-time measurements conducted daily over a time of more than a year confirmed that the emission of all points on the body displays a clear dependence on the various known biological rhythms (24 hours, weekly, monthly). Measurements on symmetric points on both sides of the body led to the tentative assumption that symmetric measurement values may indicate healthy states while right-left asymmetricities are an indication of disturbances. Most interesting is the recent finding that the changes of the biophoton emission after some treatment were not only observed at the position of treatment, but also appeared at other places of the body. These non-local effects seem to demonstrate that the local biophoton emission is an expression of a global biophoton field of the whole organism.

A new picture of the organism

The experimental findings of biophoton research, together with recent insights from other fields of advanced science, are suggesting an entirely new picture of the living organism. First of all, as a complement to the solid body of molecules, we have an important new component or aspect of the organism to consider, namely the „electromagnetic field body" (Zhang, 2003). From this point of view, the living organism appears as a highly complex and self-tunable resonating system of oscillating fields that are coupled nonlinearly by their phase relations (Bischof, 2003). If we consider the role of the molecules, the organism can be defined as a extremely sensitive and highly effective antennae system, able to tune itself according to need to a broad range of frequencies and polarisations. The organism is able to react sensitively to the smallest stimuli, but at the same time can also abruptly become transparent for quite strong stimuli.

Applications

Since the onset of biophoton research, various applications have been developed by Popp's group and the other labs. Because biophoton emission reflects all external influences and internal changes of an organism, its measurement in principle can be used to determine the state of the organism and for the detection and assessment of all types of influences, even if their nature is not known. Besides the use of biophoton measurements for chemiluminescence detection, the method can be used for the detection and damage assessment of environmental contamination by all types of solid, liquid, and gaseous chemicals, and electromagnetic fields. Another application that is already used in practice is food quality assessment. Some medical applications are under development, but not yet completely ready for use. For instance, it has been found that cancer tissue displays completely different biophoton emission characteristics that healthy tissue of the same type. This could be used for developing a non-invasive method of cancer diagnostics, and also could serve to determine the optimal therapeutic treatment for a particular patient. Biophoton measurements have also widely been used to assess the effects and effectivity of various therapeutic modalities, mainly in the field of alternative and complementary medicine.

However, it is in another field where biophoton research has maybe been most influential. Biophoton theory – the new holistic picture of the organism developed by Popp on the basis of his experimental findings – is being used by an increasing number of scientists and medical doctors as an important element and stimulus for developing an adequate scientific theory of life, the need for which is felt by a growing number of them (Ho, 1993; Zhang, 2003; Curtis & Hurtak, 2004). As I have described recently, the experimental and theoretical findings of biophoton research, together with many other scientific advances, are also an important contribution in the recent emergence of a new holistic and transdisciplinary viewpoint in the life sciences, Integrative Biophysics (Bischof, 2003).

Biophoton field and visual field

As it may be of interest to the readers of this journal, as a conclusion I will allow myself some remarks concerning vision. Some unpublished observations suggest that the state of the biophoton field of a person may be connected to the tonus and geometry of the musculature and the vegetative state of the person on the one hand, and on the other hand to the state of the brain as measured by the EEG (e.g., degree of synchronisation and coherence). Advanced states of deep relaxation or certain meditative states characterized by a high degree of coherence in the EEG measurements may well be accompanied also by a high coherence of the biophoton field. I have experienced so many moments of drastic change in the visial field when in deep states of meditation that I suspect that seeing and the visual field of a person may depend on the coherence of the biophoton field of this person that perhaps could change not only the ability to see clearly but also the visibility in the vicinity of the body. Maybe the visual field is even a property of the biophoton field itself. However, these are merely conjectures because measurements correlating the coherence of the biophoton field and the EEG readings have not yet been made as far as I know.

With his book „Biophotons" (1995, 12th printing 2004) the author has written the most comprehensive account of biophoton research published in any language, but the book is in German and has not yet been translated into English. The author can be reached at mb@marcobischof.com.

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Website of the International Institute of Biophysics:
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Comprehensive Bibliography on Biophoton Research and Related Subjects:

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