# Biophysical Aspects of the Psychic Situation

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**Abstract:**
Biological Systems are governed by the special interaction of a coherent electromagnetic field (biophotons) and biological matter. There is a permanent feedback coupling between field and matter in a way that the field directs the location and activity of matter, while matter provides the boundary conditions of the field. Since the field is almost fully coherent, the interference patterns of the field contain the necessary information about the regulatory function. The interference structures are not stable, but vary in concordance with the rather complex spatio-temporal interactions between field and matter. The dominating role of source and sink of the field is probably played by the DNA. (1) Matter, (2) energy distribution over the matter, (3) entropy, (4) information up to what we call (5) consciousness are all linked in a wholistic, hierarchical structure of interactions.
**Keywords**
Energy Distribution, Entropy, Coherence, Biophotons, Consciousness, Placebo Effect.

## Introduction and Physical Background

In the trial of explaining "life", biophysics is confined to two basic quantities, that is matter and energy. On the one hand this avoids a lot of confusion with definitions of, say, body, flesh, mind, spirit, consciousness, or soul. On the other hand, these two terms matter and energy may not suffice to describe the rather complicated phenomena that we call „life„. However, by comparing molecular biology ( which is the basis of our present understanding of life) with modern physics, one finds an alternative and deeper understanding of life by distinguishing between (1) the description in terms of molecular reactions of genes, hormones , receptors, ...., and (2) the biophysical approach in terms of the energy distribution over the whole body.

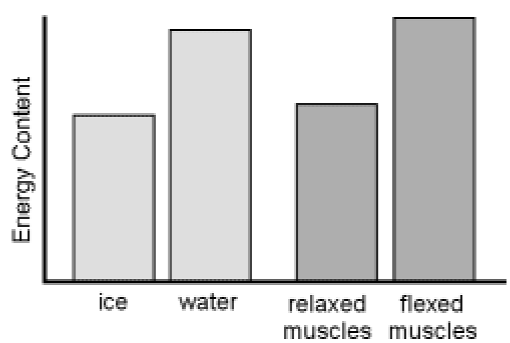


***Fig.1***
*In order to understand the properties of matter, not only the material content is decisive but also the content and distribution of the energy over matter. Examples are ice and water or relaxed and flexed muscles.*

Actually, even the properties of dead materials are not understandable by the investigation of matter alone. As an example take the case of water and ice. Both consist of the molecules H2O. However the properties are quite different. This difference is not based on different matter, but on different energy content which leads to different *entropy* of the aggregates.
The entropy indicates how the available energy is distributed over a definite arrangement of matter. It tells us, for instance, how photons (quanta of electromagnetic energy ) are occupying the „phase space„ of the system under investigation. Under „phase space„ the physicist understands not only the spatial space but also the „momentum space„ which takes into account the possibilities of taking up particles of different quantum energy and different direction of propagation. The thermodynamical probability W accounts for all the numbers of the different ways to distribute particles (like photons) to the different available quantum states of their energy

( Fay, 1965) [1].

*Take a definite quantum energy $\varepsilon$ and count the number $N(\varepsilon)$ of different ways to assign to the present $n(\varepsilon)$ particles of this energy $\varepsilon$ the $C(\varepsilon)$ available phase space cells in a given volume V. Then multiply all these numbers $N(\varepsilon)$ for all the different energy values $\varepsilon_1$, $\varepsilon_2$, $\varepsilon_3$, ..... in order to get the „thermodynamical probability W. The entropy S is defined as $S = k \ln W$, where k is Boltzmann`s constant ($k = 1.3805\ 10^{-16}$ erg/K, K representing the absolute temperature in „Kelvin„) and ln W is the natural logarithm of W.*

W and S are functions of the volume V under consideration, and of the numbers N(*) and C(*). It turns out that the entropy (or the thermodynamical probability W) is the most essential quantity in macroscopic physics, since it is responsible for the dynamics of matter, e.g. the course of chemical reactions, degradation of structures, particle flow, and distribution of mechanical or electrical potentials (pressure, electrical or magnetic forces). Even the arrow of time is based on the „second law of thermodynamics„ which states that the entropy S (or W) always takes its maximum under the boundary conditions of the system under study. Roughly speaking, this means that every system displays the tendency to arrive at the most probable state where the energy is distributed in the most uniform way.

We have to distinguish between closed and open systems. Dead matter belongs generally to closed systems where the external „heat bath„ at constant temperature provides at any instant that as much heat flows into this inactive matter as is going out from it. As a result closed systems have at equilibrium the temperature of their surroundings. Open systems, on the other hand, do not only exchange heat with the external world but also „signals„„ e.g. special electromagnetic waves or matter. Since living systems are exposed to essential signals such as sun rays („photosynthesis„) or material food, they are certainly not „*ideal*„ closed systems. On the contrary, we will see later in this paper that they are to some extent „ideal *open* sytems„.

For understanding open systems (like living ones) it is useful to compare them with closed ones in order to get an idea of the most significant differences of animated and unanimated matter. In a closed system the maximum entropy has to follow the rather basic condition that the flow of heat energy between surroundings and the system under study is always balanced. This condition provides a stationary equilibrium state. Thus, the entropy of ice, for example, has its maximum value under the condition that the temperature of the external world is low enough for taking up just as small an amount of heat from ice as it gives back. Again, at higher temperatures above 0o Celsius the entropy of water arrives at a maximum under just the same constraint that the heat production of water is compensated by the inflow of heat from the surroundings. Therefore, ice and water are closed systems. Consequently, the common property of both is the maximum of entropy under the constraint of energy conservation. The essential difference between ice and water, then, has its origin simply in the different energy densities. Maximum entropy in closed systems requires a definite temperature T as well as a definite occupation of the different energy levels $\varepsilon_1$, $\varepsilon_2$, $\varepsilon_3$,.... with photons of energy $\varepsilon_1$, $\varepsilon_2$, $\varepsilon_3$, ....known as Bose-Einstein - statistics (or, in the optical range, Boltzmann-distribution, $n(\varepsilon) \propto \exp(-\varepsilon/kT)$). It states that with increasing temperature T, the number $n(\varepsilon)$ of (thermal) photons increase, and with increasing quantum energy $\varepsilon$ of the excited states, the number of photons of energy $\varepsilon$ drops down exponentially. As a consequence, „dead„ material displays in general no chemical reactivity, simply because there are not enough photons available to trigger internal reactions of high activation energy $Ea = \varepsilon = h\upsilon$. However, every chemical reaction takes place in such a way that at least one of the reaction partners has to be excited by a photon of suitable energy Ea in order to build up a transition state complex that works as the necessary first step of chemical reactions (Lehninger, 1975) [2]. (Fig.2).

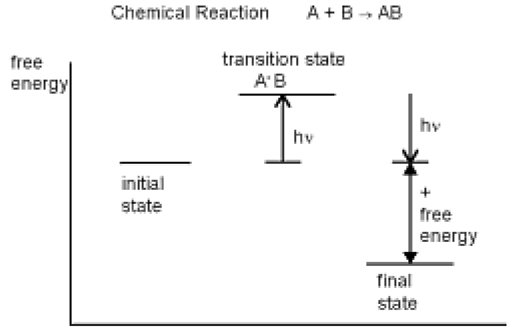


***Fig.2***
*Every chemical reaction takes place if, and only if, at least one of the reacting compounds is excited by a photon of suitable activation energy Ea= $h\nu$, where $\nu$ is the frequency of the activating photon, and h is Planck`s constant. This means that (1) without photons chemical reactions are not possible and (2) the distribution of photons regulates the chemical reactivity in non-living and living matter.*

## Introduction and Physical Background (2)

In closed systems only at rather high temperatures do enough thermal photons of suitable quantum energy Ea (in the optical range) become available for chemical reactivity. The sun or high-temperature lamps are examples. At physiological temperatures in living systems the amount of thermal photons would be several orders of magnitude too small to explain the rather high reaction rate of $10^5$ reactions per second and per cell (Popp, 1998a) [3].
Actually, we *do* measure in *living* matter
(1) several orders of magnitude higher photon intensities („biophotons„) than in closed systems at physiological temperatures (Fig.3),
(2) distinct deviations from a thermal system in such a way that it is not possible to assign a constant temperature to the photon density in the optical range from at least 200 to 800 nm (Fig.3).

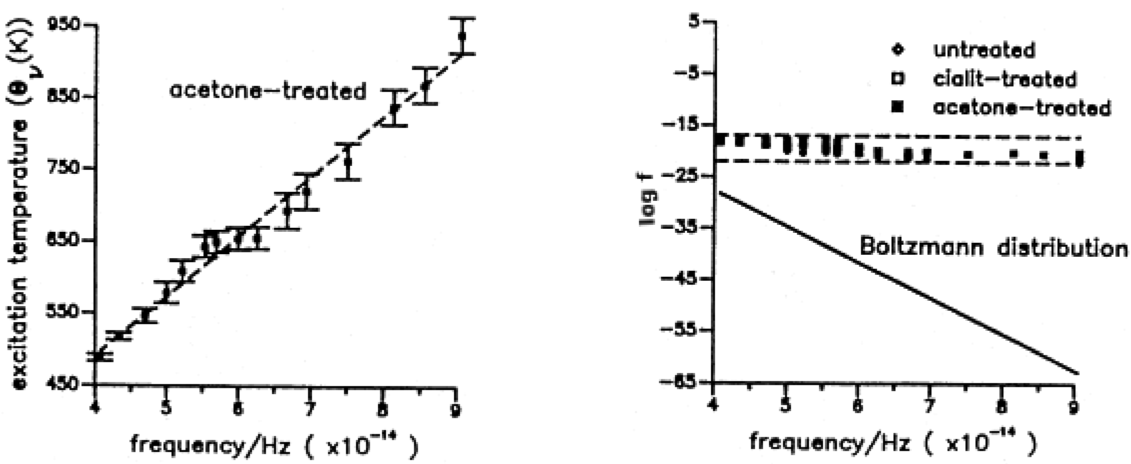


***Fig.3***
*The measurements of biophotons show that the spectral intensity in the range from 200 to 800 nm is orders of magnitude higher than expected from thermal photon emission.*
*If one displays instead of spectral intensity the excitation temperature $\theta(\varepsilon)$ which corresponds to the temperature of a closed system of just the same spectral intensity of photons as the actually registered one, it turns out that biophoton emission is governed by the law $\theta(\varepsilon) \propto \varepsilon$ (upper Fig. 3). The $\theta$-values are much higher than the physiological temperature. This means that the biophoton field is certainly not heat radiation. Rather, this field stabilizes far from thermal equilibrium It corresponds to a system where phase space cells are occupied with the same probability, taking the absolute highest possible value of entropy (lower Fig. 3, upper curve). This distribution is far from the Boltzmann distribution of a closed system (lower Fig.3, lower curve).*

These remarkable features which are nowadays generally accepted (since they have been confirmed in all the laboratories that perform biophoton measurements (Chang, Fisch, and Popp, 1998 [4]) throw a completely new light onto the understanding of living systems.
First, it is evident that the metabolic activity in animated matter is governed by biophotons since they (and only they) can be responsible for the triggering of all the necessary transition state complexes with activation

energies in the optical range. Heat photons would never suffice to provide the necessary activation energy. Even enzymatic reactions cannot take place without this activation by suitable photons.
Second, it is clear that this regulation principle is not based on a chaotic energy distribution such as thermal equilibrium but has the capacity of controlling the biological functions at the right time in the right position. This does, by the way, not require extremely high photon numbers. Since after a small reaction time of about $10^{-9}$ seconds the activating photon is *not* thermalized but available for the next reaction (Cilento, 1988)[5], one photon can trigger at most $10^9$ reactions per second, provided that it always dirigates the activation of the transition state at the right time in the right place.
This is not just a question of energy or photon number, but of the information that is necessary to distribute the available energy in the right way. It belongs to the most fascinating problems of biophoton research to find out in what way biophotons dirigate the biological functions.
A first approach to answering this question is to look at the entropy in living systems. One expects that the "order" of living matter is higher the lower the entropy. But how do we achieve this at low energy if the maximum of entropy is the essential governing law of macroscopic dynamics? In order to solve this problem one has to remember that the maximum of entropy in closed systems is achieved under the rather strong constraint of energy conservation law. What happens if we cancel this constraint? And what does it mean to cancel this condition? The answers are quite important for understanding "life". As soon as a closed system is not confined to energy conservation the thermodynamical probability (or the entropy) becomes higher. It then takes its maximum if, and only if, all the available quantum states are occupied with *just the same probability* instead of following the Boltzmann distribution. Hence, instead of the exponential decrease of photon number with increasing activation energy, all the different energy levels contain the same number of photons. With the exception of small deviations, this is just the measured spectral distribution of biophotons (lower Fig. 3, upper curve). Consequently, we have reason to trace this experimental fact back to the case where the confinement to the energy conservation law is abandoned. At the same time, the lack of energy conservation means simply that the same amount of biophotons that flows out is not always compensated by the influx of the same number of photons. Rather, there is always enough energy available for the creation or availability of biophotons providing then a permanent continous photon current from living matter. Actually, this is quite obvious.
But instead of approaching a state of low entropy we arrive now at a state where the entropy has its absolute maximum even at higher values than in comparable closed systems of the same energy content. How do we explain this apparent contradiction?
At least we are now sure that this state of highest possible entropy does not violate the maximum entropy principle.
Even so, the way to arrive at rather low entropy, which may theoretically take the lowest value 0, is simply what physicists call Bose condensation. As soon as very small cooperative interactions between the quantum states of the whole system come up, the photon gas becomes "frozen" on account of a dramatic reduction of the degrees of freedom. An extreme limit of this process is represented by a system with only one degree of freedom. It displays the entropy 0 which - and this is the puzzling result - takes even furthermore the formal maximum (!) value under the actual boundary conditions. The absolute value 0 and the entropy maximum *thereby do not contradict each other*. Rather, they do not violate the second law of thermodynamics at all. These circumstances constitute what I call an "ideal open" system. At the same time, this system has the highest possible sensitivity since *smallest amounts of* energy uptake or removal may induce dramatic changes of entropy in terms of the corresponding increase or decrease of the number of degrees of freedom. Fig. 4 displays this situation.

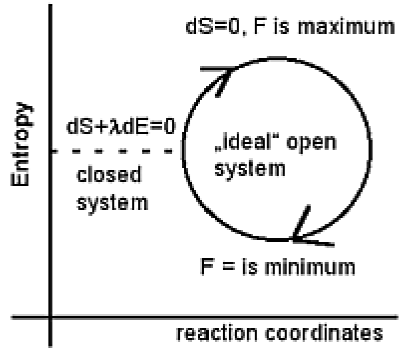


***Fig. 4.***
*Compared to the entropy S of a closed system (dotted line), the entropy S of a living system (continous line) at constant energy E is rather variable. The entropy of animated matter is always an absolute maximum, where only the number F of degrees of freedom changes between complete separation (where the entropy is even higher than for the case of thermal equilibrium) and complete coupling (where the entropy can take even the value 0).*

It should be noted that evidence of this "mode coupling" of biophotons has already been demonstrated, i.e. the same relaxation function of all modes after exposure of a living system to external light illumination of different wavelengths (Popp et al., 1992)[6].
It is worthwhile to note that processes of this kind do not violate the second law of thermodynamics. Closed parts of the system under consideration are further subject to entropy increase, where the field may in part take lower values by condensation and other parts (to which the external world belongs) will increase the entropy, e.g. by uptake of higher entropy photons.
In this picture biological systems are squeezed in between the tendency of increase of entropy in terms of decoupling of modes (individualization, like cell growth) and coupling (holistic integration, like cell differentiation, establishing there higher states of organization).
The mechanisms are not yet clear. However, there are a lot of indications pointing to exciplex formation in the DNA (Li, 1981)[7].
We will not go deeper into the details of the models here. But one has to point out that a final explanation can be given only in terms of quantum optics. One of the most crucial points is the coherence of biophotons. This provides the highest possible "visibility" as well as optimal properties for communication and information. Actually, we already showed evidence of an almost perfect quantum coherence of biophotons by demonstrating three properties, where two are necessary, one sufficient, and all together are sufficient conditions for quantum coherence of the biophoton field.The first is the significant deviation from thermal equilibrium (see Fig.3), and the second one is the Poissonian distribution of the photocount statistics. If one counts the numbers of biophotons which are emitted during a preset time intervall $\Delta t$, one gets a time series of count numbers. Ordering these measurement values in terms of the frequency of registering 0,1,2,.., n photons, one gets the probability distribution $p(n, \Delta t)$ for measuring n = 0,1,2,.... photons in the fixed and preset measuring time interval $\Delta t$ during the measurement time 0 up to t, where $\Delta t \ll t$. For a fully coherent field, $p(n,\Delta t)$ follows a Poissonian distribution. All the biophoton researchers agree now that biophoton emission is actually subject to Poissonian photocount statistics (Chang et al., 1998)[4]. However, this is a sufficient condition of coherence only for $\Delta t \leq \tau$, where $\tau$ is the coherence time of biophotons. Consequently, we need further proof, since $\tau$ is not known at present. This proof has been performed (Popp and Li, 1993)[8] by showing evidence that the relaxation function of "delayed luminescence" of biophotons follows an hyperbolic (1/t) rather than an exponential exp (-ßt) law, where t is the time after exposure of the living system to an external light illumination and ß represents the decay constant (Fig. 5).

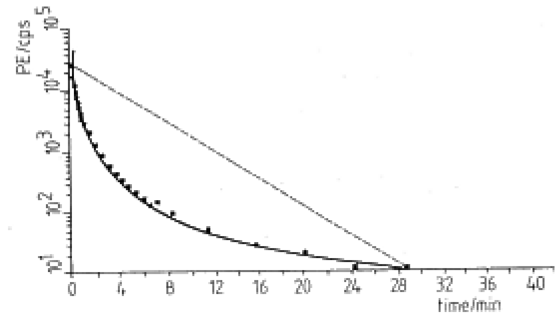


***Fig.5:***
*Instead of an exponential relaxation (dotted line), biological systems always display an hyperbolic relaxation to the „delayed luminescence„. This is in the case of an ergodic system (which is subject to a Poissonian distribution of the photocount statistics) a proof for perfect coherence of the biophoton field. This curve shows the „delayed luminescence„ of a leaf at a definite wavelength.*

It should be noted that these features of biophotons characterizes animated matter as a subject of coherent states where every part is connected to every other part, constituting in this way an integrative, holistic system. Fig. 6 displays a striking example of this kind of regulation (Popp, 1979)[9].

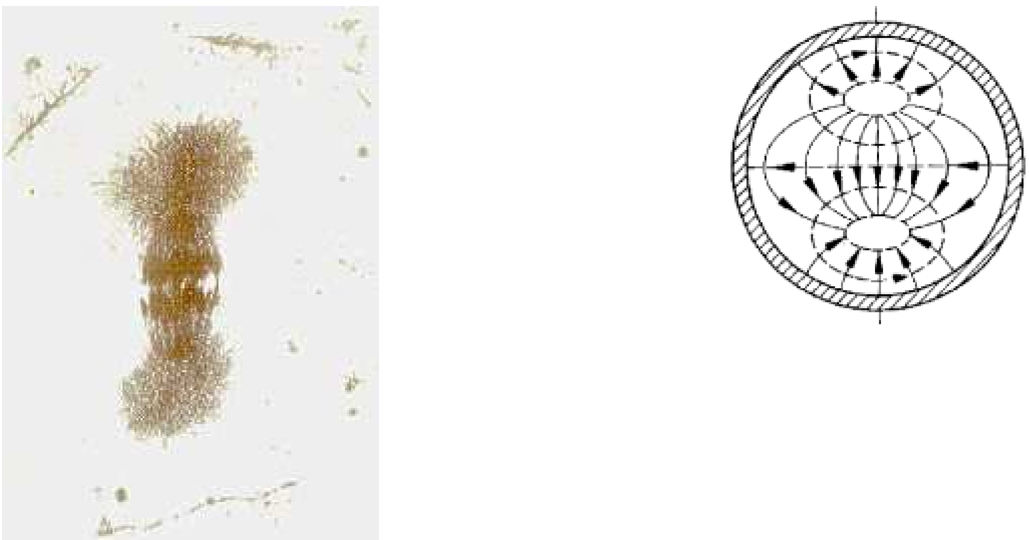

***Fig.6:***
*Mitotic figures are controlled by the coherent field of cavity resonator modes which are stabilized under the boundary conditions of the interacting matter. In this way biological systems are governed by the coherent feedback coupling of the biophoton field and matter. Mitotic figures show evidence of holistic regulation.*

## Biological Impacts and Consciousness Research

From the biophysical point of view biophotons are regulating the body in its rather complex functions. The interference pattern of biophotons originating from the resonance tuning between the coherent field and biological matter (preferentially DNA) governs the availability of energy in a concerted action of the whole. Consequently, the organizational capacity is reflected by characteristics of biophoton emission.
Actually, Fig. 7 displays the photon flux from germinating seeds (Popp, 1998a). The essential feature is the oscillatory fluctuation around values that correlate2 significantly with the growth rate. A mathematical analysis reveals the quadratic dependence of the emission on the number of photons as well as on the cell number. This means that the organization in living systems is not based on "nearest neighbour interactions" as, for instance, in solids, but on the rule that every part is connected to every other part. Fluctuations around this law can be most seriously interpreted in terms of the entropy fluctuations seen in Fig. 4. They have regulatory activity as well.

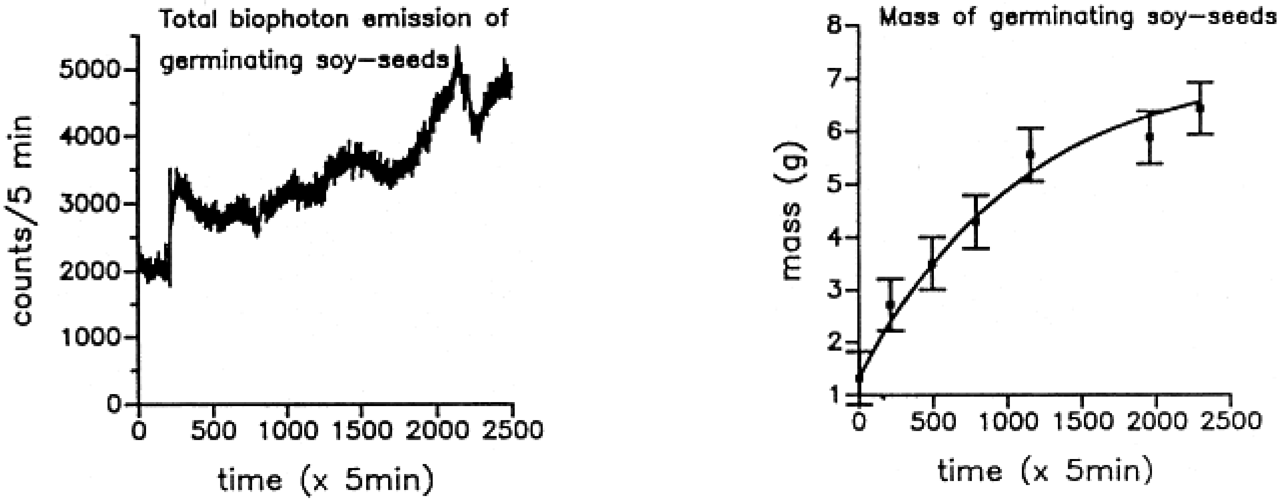


***Fig. 7:***
*The biophoton emission of germinating seeds (left side) correlates to the growth rate (right side). However, the fluctuations in biphoton emission show the more sensitive regulatory activity of biophotons, reflecting changes in the entropy, while the growth rate as a consequence of the biophoton field is more smoothed out.*

Striking examples of this principle are the biophoton emission of daphnia (Galle et al. 1991)[10] (Fig.8) and the "delayed luminescence" of tumor cells compared to that of normal cells (Schamhart and van Wijk, 1987)[11] (Fig.9).

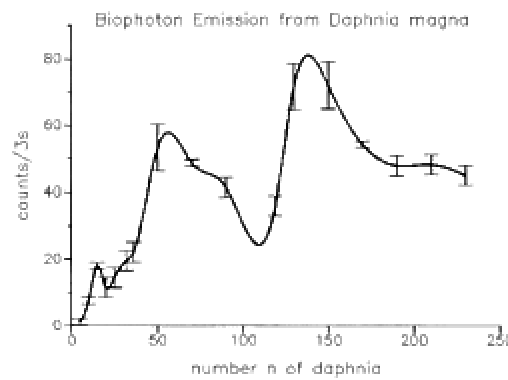


***Fig. 8:***
*The biophoton emission of daphnia depends on the mean distance between the animals. Dependent on the number of daphnia in a cuvette the biophoton emission shows minima and maxima which can be traced back to the capacity of the biophoton field for displaying destructive interference in the extracellular space and constructive interference within the cells.*

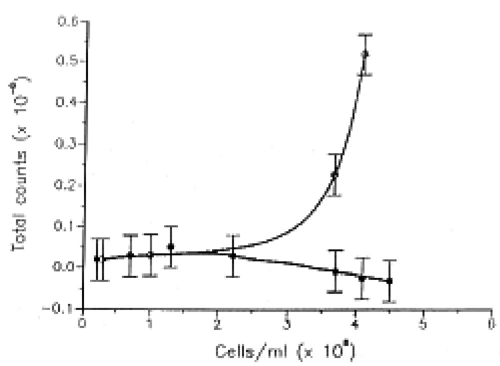


***Fig.9:***
*The delayed luminescence of normal cells (lower curve) follows qualitatively different dependences on the cell density than that of tumor cells (upper curve). While normal cells show induced absorption of photons, tumor cells are subjects of induced emission.*

These rules do hold not only for cell populations and organisms, but also for organs within a body and even for the development of consciousness.
In order to show the link, let us start with a rather simple example.
It is well known that the basic nutrition of living systems is light. Actually, plants take it up directly from the sun, while mammals absorb it by metabolic degradation of sugar that contains sunlight in the form of the binding energy of $H_2O$ and $CO_2$. Sugar is digested into water and carbon dioxide which both are excreted by

breathing, respiration, sweating and urinating, while the stored sun energy becomes available for activation of biological functions. From the physical point of view this activity corresponds to a photon store which can always be characterized by its so-called resonator value Q. Q is defined as the ratio of stored energy U to lacking energy i (Q=U/i). The higher the Q-value is, the higher is its storage capacity. The essential point is that Q describes as well the potential information which can be transferred by the stored electromagnetic energy. The higher the Q-value, the higher the potential information of the system under consideration.

From a teleological point of view biological systems use sun energy in order to build up high-density informational stores which delay the thermal dissipation in the most effective way. This is completely in line with the characteristics that have been derived in the first part of this paper. However, the model of a resonator connects in the most simple way the phenomena of biophotonic organization with information. As an example take the information that is necessary to regulate the $10^5$ biochemical reactions per second and per cell during the metabolic program of one day. An estimation yields necessary information to be about $10^{12}$ to $10^{14}$ bits, corresponding to a coherence time of $10^{-3}$ to $10^{-1}$ s. These time intervals account for the storage capacity of the resonator, since Q can be expressed in terms of the decay-time $\tau$ of the stored modes and their frequency n, i.e. $Q=\nu\tau$. Actually, at least in this range of milliseconds or higher one finds the relaxation time of delayed luminescence of single cells. However, the linear resonator is too simple a model for explaining decisive features of living systems based on quantum coherence. In order to show this and at the same time the link to consciousness, let us compare the linear with a non-linear resonator.
We assume that consciousness is a process of transforming actual into potential information and vice versa, and we optimize this process by optimization of the Q-value. This is consequent since the potential information (as the world of possibilities) has to be assigned to the stored energy while the actual information (as the world of actual events) is expressed in terms of the measurable photon intensity. Consequently, the optimization procedure requires that

$$Q(T) = \int_0^T \nu \frac{U}{i} \, dt \overset{!}{=} \text{Extremum}$$

The linear case corresponds to U µ n and i µ, where n is the number of stored photons and the lacking photon current. Hence we have:

$$Q(T) = \int_0^T \nu \frac{n}{\dot{n}} \, dt \overset{!}{=} \text{Extremum}$$

The solution is an exponential function ($n \propto \exp(-ßt)$), where ß is the decay constant and t the time. However this kind of store has no fixed memory since the measurement values between two consecutive points of time $t_1$ and $t_2$ depend only on the time difference $t_1$-$t_2$, but not on the original time of excitation. This means that this system is unable to develop consciousness.
There is a further solution to this problem which is optimized on a higher level of organization. In this case, $U \propto n^2$. This means that every particle of the system is connected to every other part, providing optimal communication.

$$Q(T) = \int_0^T \nu \frac{n^2}{\dot{n}} \, dt \overset{!}{=} \text{Extremum}$$

The solution of this equation takes a hyperbolic function $n \propto 1/t$ which displays a theoretically infinite memory since the registration of consecutive events in time keeps the information of the original event. $1/t_1 - 1/t_2$ is not only dependent on the time difference $t_1$-$t_2$, but also explicitly on $t_1$ (or $t_2$). Thus, it never forgets the origin of the actual event.
A further consequence of hyperbolic relaxation as a sufficient condition of coherence is the logarithmic normal distribution of physiological parameters (like blood pressure, tolerability of remedies, conductivity of the skin) which is well known in medicine (Zhang and Popp, 1994).

In conclusion, these experimental facts derived from biophoton research and the theoretical analysis invites the following picture of hierarchical structure of biological organization (Fig. 10).

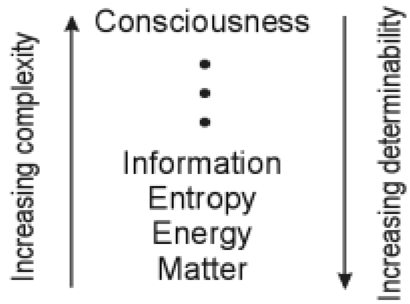


***Fig. 10:***
*There is a hierachical order of terms which may describe the organization of living systems. On the base, is matter itself, then energy, then the distribution of energy over the matter (entropy). This induces and describes what we call "potential" information, after which we arrive at its highest organizational form, what we call "consciousness" (Popp, 1992)* [12].

In order to show the practical relevance of the intimate connection between the biophysical and the psychic situation, let us take the actual problem of placebo effects. In ordinary discussions, the "placebo effect" is based on the belief in the doctor`s capacities. However, the link between the organization of the body and the mind is neglected in this model. Rather, one has to provide that the "belief" in one's own health and the resultant actual health are not separable phenomena. As soon as one is healthy (or almost healthy), the body displays the necessary coherence in the biophoton field. The coherence of the field, on the other hand, induces the "belief" in and conviction of one's health. On the other hand, if this conviction is not manifested, real health will not be manifested in the patient. In the course of time it is impossible to have this conviction without "health" or to be healthy without this "belief" in it. Compared with this plausible connection between "body" and "mind", the induction of health by "belief" in a doctor is rather unlikely. Consequently, we would like to postulate that homeopathy induces real and probably long-range organizational effects within the body (Popp, 1998b)[13] ,in cases where some scientists have traced the healing back to placebo effects. We even have reason to claim that every kind of healing has to be focussed onto the improvement of the special coherence of the living matter in order to induce the belief (conviction) of the patient in (of) his own health.

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