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THE ACTION MECHANISM OF LOW LEVEL LASER RADIATION ON CELLS: OUR HYPOTESIS

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The low level laser (LLL) therapy has been expanding ever since it evolved from laser technology and is gaining increasing experimental, medico-scientific, clinical and therapeutical experience. Frequent indications range from the stimulation of endogenous healing to cosmetic treatment, especially in case of skin applications. Up to this day, however, there are only inconsistent ideas of how LLL radiation, which – depending on the desired penetration depth – is accompanied by energies from the visible to the infrared spectral region, acts on the cell. As regards this mechanism, it is therefore the object of the following exposition to present a model on a cellular level that is consistent in itself /1, 2/.

In the past years, the LLL therapy has enabled the authors to obtain very good healing results with chronic inner ear diseases (see figure 1), chronic pain conditions and chronic skin diseases as well as orthopedic and acute general diseases such as bronchitis, sinusitis, middle ear infection, herpes simplex, acne etc.

Fig. 1. LLL therapy of infantile inner ear deafness

It is particularly due to the successful LLL therapy of both complex chronic inner ear diseases with or without tinnitus (noises in the patient`s ears) in consequence of continuous loud noise, explosion traumas or sudden hearing loss and otogenous vertigo (menière`s syndrome), that the authors have been confirmed in their daily work for years /3/.

Although it`s doubtlessly the application of energy by means of LLL radiation that regenerates affected cells and hence the organism, the action mechanism still fails to be explained in a biochemically consistent way. For lack of a conclusive conception, one generally ascribes the healing process to the stimulation of the microcirculation respectively the body`s defences or simply resorts to emphasizing the LLL radiation`s overall positive effects.

The energetic provision of the cell

Healthy cells distinguish themselves by being optimally provided with energy. This energy derives from the ingestion of foodstuffs and reaches the cell by means of fission into absorbable parts. As the organism cannot utilize the chemical energy of nutrients directly, however, it first has to convert it into a cellularily usable form. Absolutely central to this process is adenosine triphosphate (ATP), which is oxidized through reduction (donation of energy-rich electrons) to ADP respectively cAMP and is the most important form of the energetic provision of the cell.

The biochemical/biomechanical model of the cellular energy transfer

In biochemical/biomechanical models of the cellular energy transfer, electrons functioning as energy-carriers are held responsible for the various stages of the conversion process in the cellular energy transport /4, 5, 6/. Via the blood, the absorbed and already partially degraded food particles reach the organs, where they continue to be broken down by the enzyme-mediated catabolism of the corresponding parenchyma cells. The biochemical reaction chains accountable for this degradation are: a) the extra-mitochondrial glycolysis with reduction to the electron-donating NADH, b) the generation of pyruvate that is broken down on the inner mitochondrial membrane in the citric acid cycle and c) the metabolization of simple fatty acid chains entering the mitochondria coupled to carnitine.

According to the prevailing models, the energy-rich electrons thus yielded are passed on to the respiratory chain of the inner mitochondrial membrane by means of several oxidation-reduction reactions. This process is thought to be the result of random collisions of the electrons with either membrane-bound proteins or the immediate component parts of the respiratory chain.

In the course of the transfer, the electrons lose their high initial energy, which now serves to create a proton gradient driving oxidative phosphorylation and, consequently, the production of ATP. As for the aerobic metabolism, this process is the main source for the synthesis of ATP.

Contradictions and inconsistencies in the biochemical/ biomechanical model of the cellular energy transport

The first discrepancy in the biochemical/biomechanical model of the electron flow is the very structure of the mitochondrial membrane, which is impermeable to the passage of the NADH reduced by the extra-mitochondrial glycolysis.

Besides, the various component parts of the respiratory chain contain different electron-carriers such as cytochromes, flavins or iron-sulphur complexes. At present, these carriers are thought to pass along the electrons from NADH or $FADH_2$ to oxygen in a series of transfers, while proton pumps in the mitochondrial matrix maintain a membrane potential that supports the electron flow (proton

motive force). The active centre of the electron-carriers are their prosthetic groups consisting almost exclusively of reactive transition metals. According to the model, the electrons are passed on from one metal centre of an electron carrier to the next by rotatory and translatory motions and so lose their initial energy. Nevertheless, one still cannot explain the fact that every NADH donates two electrons, for instance, while every O_2 molecule needs four electrons to generate water.

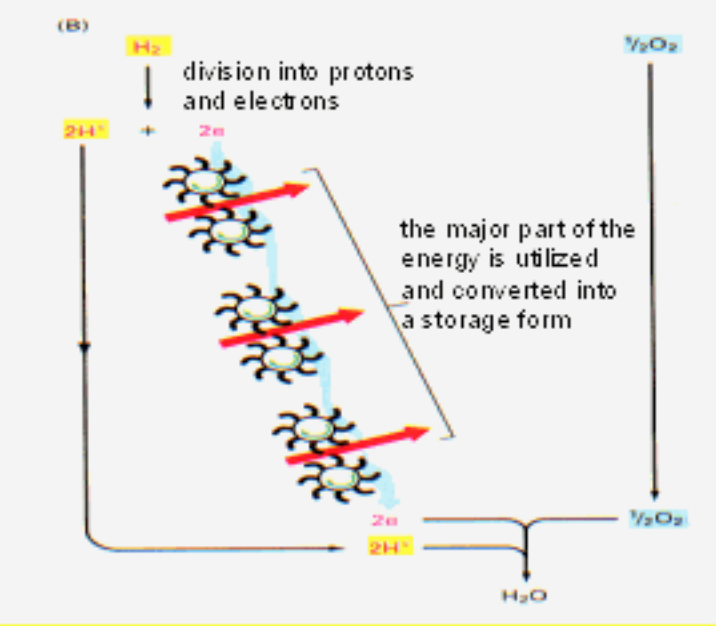

Fig. 2. Strongly schematized representation of the corpuscular energy transfer /4/

With regard to quantity, a corpuscular concept of the electron flow would therefore demand the existence of several electron collecting and distributing points along the respiratory chain, where differences in the number of electrons have to be balanced. Until the electrons are eventually passed on to O_2, the electron-transferring potential serves to supply three oxidative phosphorylation complexes through the reduction of NADH respectively $FADH_2$. In consequence, the major part of the released energy can be passed on directly instead of being lost to the environment in the form of heat. The corpuscular concept starts from the assumption, though, that the reaction takes an indirect course and hydrogen atoms are divided into hydride ions (H^- and H^+), that is, into protons and electrons, which – but for a few incidental encounters - only combine again at the very end of the respiratory chain.

And that is what the biochemical/biomechanical model is all about, regarding the processes in the cell as random and chaotic occurrences without any synergetic precision. As mentioned above, the electrons are thought to be transferred to the respiratory chain as a result of incidental encounters, which are explained in terms of vibrations and rotatory motions of the parameters involved that go as far as the quantum-mechanical tunnelling of membrane barriers. /7/. According to the corpuscular concept, this can not least be attributed to the fact that the velocity of the observed electron transfer corresponds with the expected frequency of random collisions between the mobile electron carriers and the enzyme complexes. Up to now, the presumed incidentalness of these encounters is connected to the notion, however, that there is no need for demanding a firmly established structural order of the electron-transport chain. Furthermore, it was as

yet not deemed necessary to make the well-ordered electron transfer postulated in the biochemical models solely contingent on the specificity of the functional correlation between the component parts of the respiratory chain.

These inconsistencies and the reasons given in the following clearly suggest that the mitochondrial energy transfer is associated with radiation phenomena.

From the particle aspect to radiation phenomena

By taking into consideration radiation phenomena, which - on account of the particle-wave-dualism /8/ - are an integral part of the nature of electrons (J. J. Thomson, nobel prize für physics in 1906, and G. P. Thomson, nobel prize for physics in 1937), the corpuscular electron transfer associated with the mitochondrial electron flow can also be described as a radiation process.

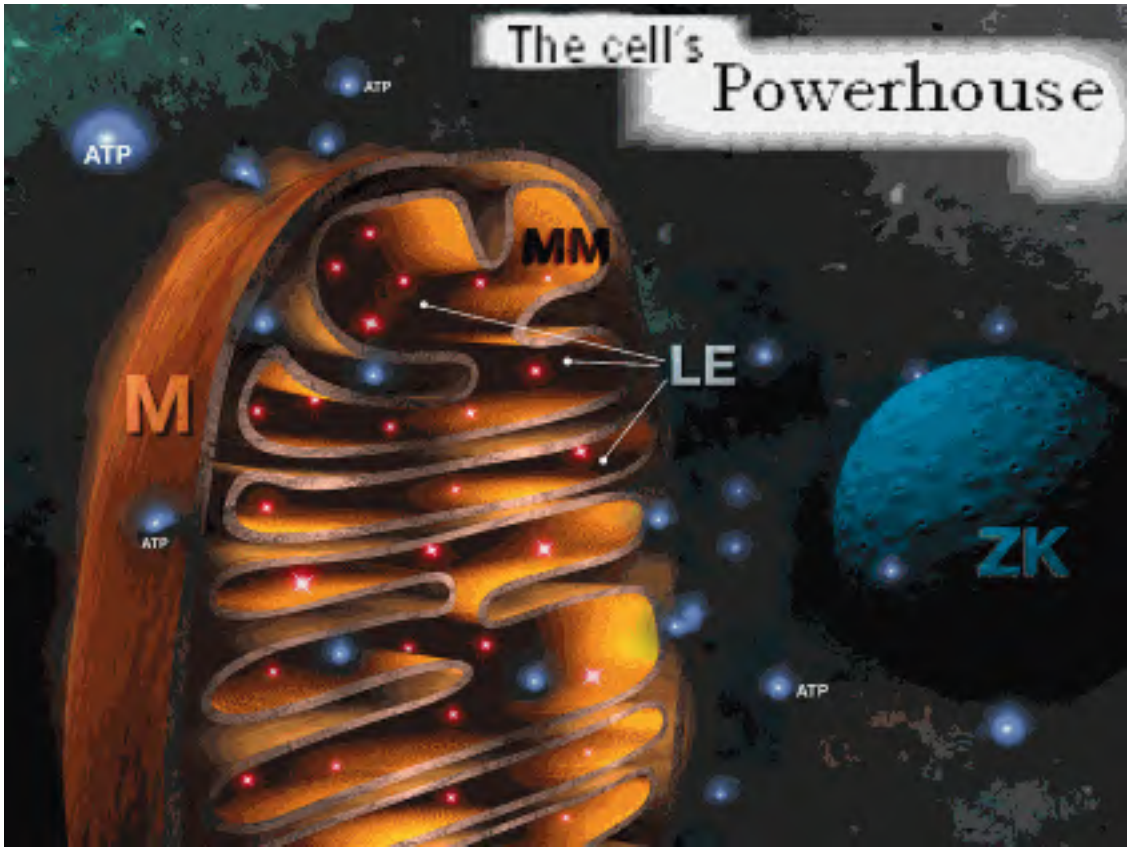

Fig. 3. Fuelled by light energy (LE), the cell`s powerhouse - the mitochondrion (M) - generates the main source of cellular energy: ATP

Contrary to the random and chaotic organization of the mitochondrial energy transfer assumed in the classic corpuscular model, functional movements and changes in the cell take place in a highly ordered way /9, 10/. Otherwise, the feedback control system cell and the entire human organism would not be able to exist in the end. This control principle is only functioning properly, however, if the highly structured processes can be attributed to long-range correlations between the various components and systems, which far exceed the radius of action of chemical forces. As this in turn suggests the vibrational aspect of matter /11/, one cannot help dissassociating oneself from an exclusively molecular point of view. With regard to the theoretical model, the mitochondrial electron flow thus turns out to be a wave instead of the classical molecular shifting of particles.

The correlation between energy transport (radiation) and order (molecular structure) becomes apparent when structurally bound energy is released in consequence of the breakdown of compounds in molecular units or released energy manifests itself again in structural form. There is, in other words, an interactive relationship between energy and structure, a circumstance that is not only in much better accordance with the modern physical quantum models, but also explains and describes the aspect of the electron flow involved in the mitochondrial energy transfer in a way that is much more logical than the prevailing concepts, which are rather hard to grasp. Essentially, chemical reactions in the cell consist of the division or combination of cellular reaction partners. Examples for this are the oxidation of foodstuffs in the citric acid cycle and the production of ATP in the respiratory chain. If reactions are to take place at all, the components involved have to receive enough kinetic energy to meet. Furthermore, at least one of the reaction partners has to be activated – and be it only for a short time - to alter its electric charge, for instance, before it can combine anew /11/.

In the cell, the presence or absence of energy-rich radiation of a certain frequency, wavelength, intensity, diffusion and polarization decides whether reactions take place or not. We will discuss this in the following on the basis of the correlation between electromagnetical radiation and the components and systems of the mitochondrial

energy transfer, focussing first on the energy ranges relevant to the energy carriers. These cellular energy ranges can best be shown by means of the systems primarily involved in the energy transfer /18/:

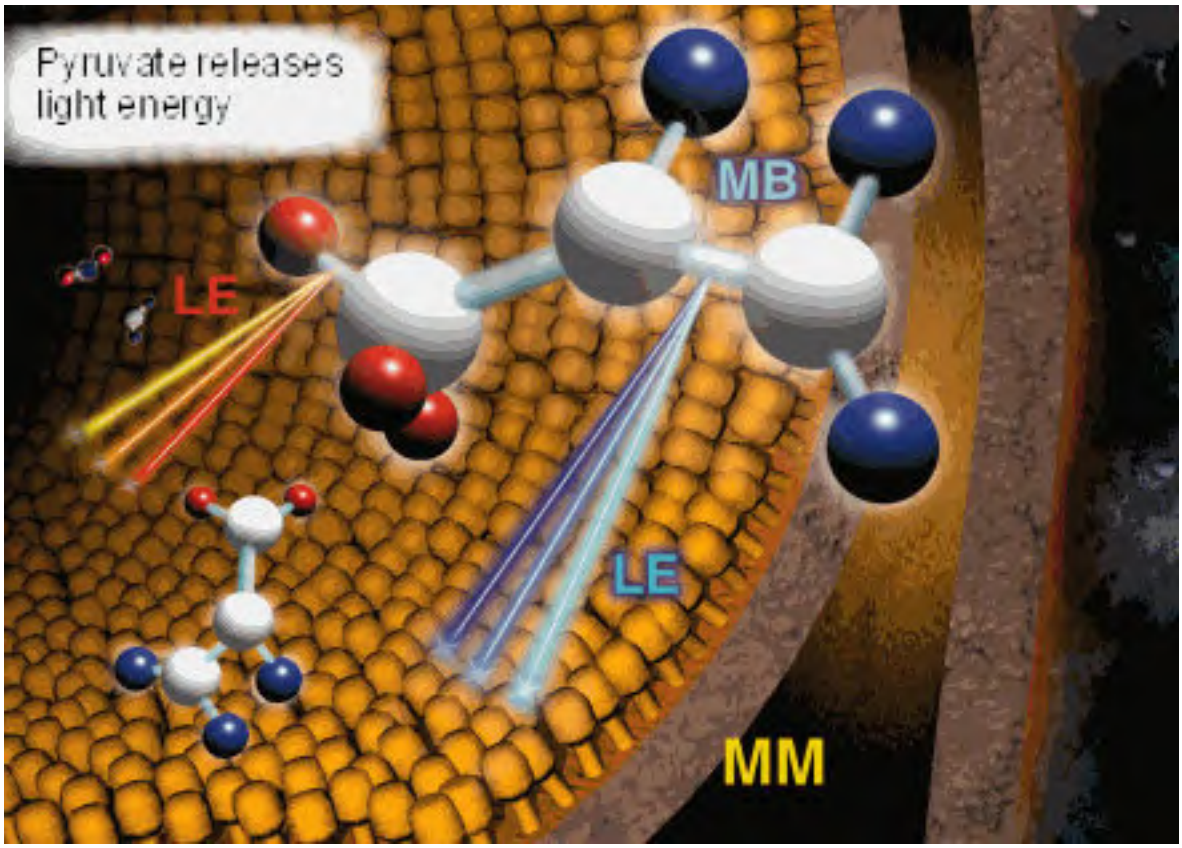

Fig. 4. The energy transfer of the molecular electromagnetic bond energies (MB) from pyruvate to the inner mitochondrial membrane (MM) shown as a radiation process (LE)

Presenting the bond energies of different kinds of chemical bonds in the cellular catabolism of foodstuffs that are broken down in the citric acid cycle /13/, table 1 shows characteristic energy ranges for the main bond energies of chemical bonds: van-der-Waals, hydrogen, covalent and ionic bonds.

Chemical bond	**ENERGY** as wavelength (nm) of electromagnetic radiation
Van-der-Waals-bond	31.100 – 15.300 (infrared)
Hydrogen-bond	950 - 410 (infrared, visible light)
Ionic bond	620 - 310 (visible light, UV-A)
Covalent bond	560 - 160 (visible light, UV-A, UV-B, UV-C)

Table 1 : Comparison between the characteristic energy ranges of different chemical bonds and the photon energy of electromagnetic radiation (given in wavelenghts of electromagnetic radiation) /13,14/.

The energies in table 1 are given as radiation energies in wavelengths of electromagnetic radiation. The representation of chemical bond energies in energies of electromagnetic radiation is based on the relation set up by Einstein that the energy E of electromagnetic radiation in Joule [J] is in inverse proportion to the wavelength λ in meters:

$$E = h \cdot \frac{c}{\lambda}$$

with h: Planck constant (= $6{,}6256 \cdot 10^{-34}$ Js),

c: velocity of light (= 2,9979 · 10^8 m/s) and

λ : wavelength of electromagnetic radiation in m.

In comparison to the wavelengths of the spectral region of the electromagnetical radiation that is visible to the human eye (they measure approx. 400 – 800 nm), the bond energies of chemicals bonds in table 1 essentially keep within the same energy range of visible light, partly reaching as far as the infrared and ultraviolet region of electromagnetic radiation. The bond energies of hydrogen bonds, for instance, roughly correspond with wavelengths of the low-energetic region of visible light from yellow to red to the near infrared. In the metabolism of the cell, the chemical energy contained in the different kinds of bonds is released through the breakdown of bonds and then converted into a usable form. This conversion is the doing of specific molecular structures in the mitochondria, which consist of the electron donator and acceptor systems (enzymes respectively electron carriers) and the component parts of the respiratory chain. The characteristic energy ranges of these systems have been determined as well. One important transport system of energy-rich electrons is the nicotinamide-adenine dinucleotide (NAD^+/NADH) system. The absorption maxima of this system range from approx. 250 to 500 nm /4/. Another important electron-transport system is the FAD/$FADH_2$ system, which yields the same photospectroscopic bands.

The absorption maxima of the spectra mark the region of electromagnetic radiation, where the system can best absorb energy in the form of radiation. How the absorbed energy is dealt with, depends on the physical properties of the systems in question and the electronic conditions peculiar to them. Possible alterations of the energy value are due to factors such as relaxation, fluoroscence, heat conversion or dynamic conformation changes. In comparison to the energies of chemical bonds (table 1), the energy ranges correspond remarkably well with the observed components involved in the mitochondrial energy transfer. The energies of chemical bonds released from covalent carbon and hydrogen bonds in the citric acid cycle, for instance, harmonize with the absorption spectra of the NAD^+/NADH and FAD/$FADH_2$ systems.

Other relevant energy ranges emerge from the key structures within the mitochondrial respiratory chain, the so-called electron-carriers. Many of them absorb light in the visible, near ultraviolet and infrared spectral region and change their colour when oxidized or reduced. Table 2 presents a list of exemplary electron-carriers and details their absorption maxima.

Table 2: Absorption bands of the photoabsorption spectra of important electron-carriers of the mitochondrial respiratory chain /4,14,15/

COMPONENT	Absorption bands (nm)		
	Soret-Bande	β -Bande	α -Bande
NADH/NAD	300 - 340		
Flavoproteins	350 - 490	470 - 490	580 - 630
Ubichinon Q	270 - 410		
Cytochrome b	450 - 465	520 - 530	558 - 562
Cytochrome c_1	370 - 380	530	555
Cytochrome c	410 - 415	521 - 528	551 - 557
Cytochrome a	420 - 450	520 - 540	603 - 605
Cu A			830
Cu B			760
Cytochrome a_3		520 - 540	806

The absorption bands in the ultraviolet region (approx. 20-300nm) derive from the amino acids of proteins such as tryptophan and tyrosine, while the soret, β and α bands derive from the prosthetic (metallic) groups

Generally speaking, all electron-carriers can be easily differentiated by means of both their specific absorption spectrum and reactivity, and this is why it is possible to study their behaviour even in crude extracts. The flavin and heme components are particularly striking. Flavins constitute an outstanding class of green and yellow pigments that derive from riboflavin or vitamine B_2. In combination with proteines, hemes (iron-porphyrines) form a variety of colourful molecules with tints from blood-red to pea-green /5/. These metallo-proteins - proteins with iron-sulphur centres, heme groupes and copper atoms, for instance - are an integral part of the respiratory chain. Three big enzyme complexes of the respiratory chain containing such metallo-proteines are the NADH dehydrogrenase complex, the cytochrome b/c_1 complex and the cytochrome-oxidase complex (cytochrome a/a_3). As shown in table 2, a clear distinction can be made between these component parts of the respiratory chain by means of their absorption spectra (photoabsorption spectra). The short-waved absorption maxima of the spectra derive from protein, while the absorption region with longer waves usually derives from the active (metallic) centre of the electron-carrier in question. These energy ranges also correspond remarkably well with the energies released from chemical bonds (table 1) and the absorption bands of the electron donator and acceptor systems of the cell.

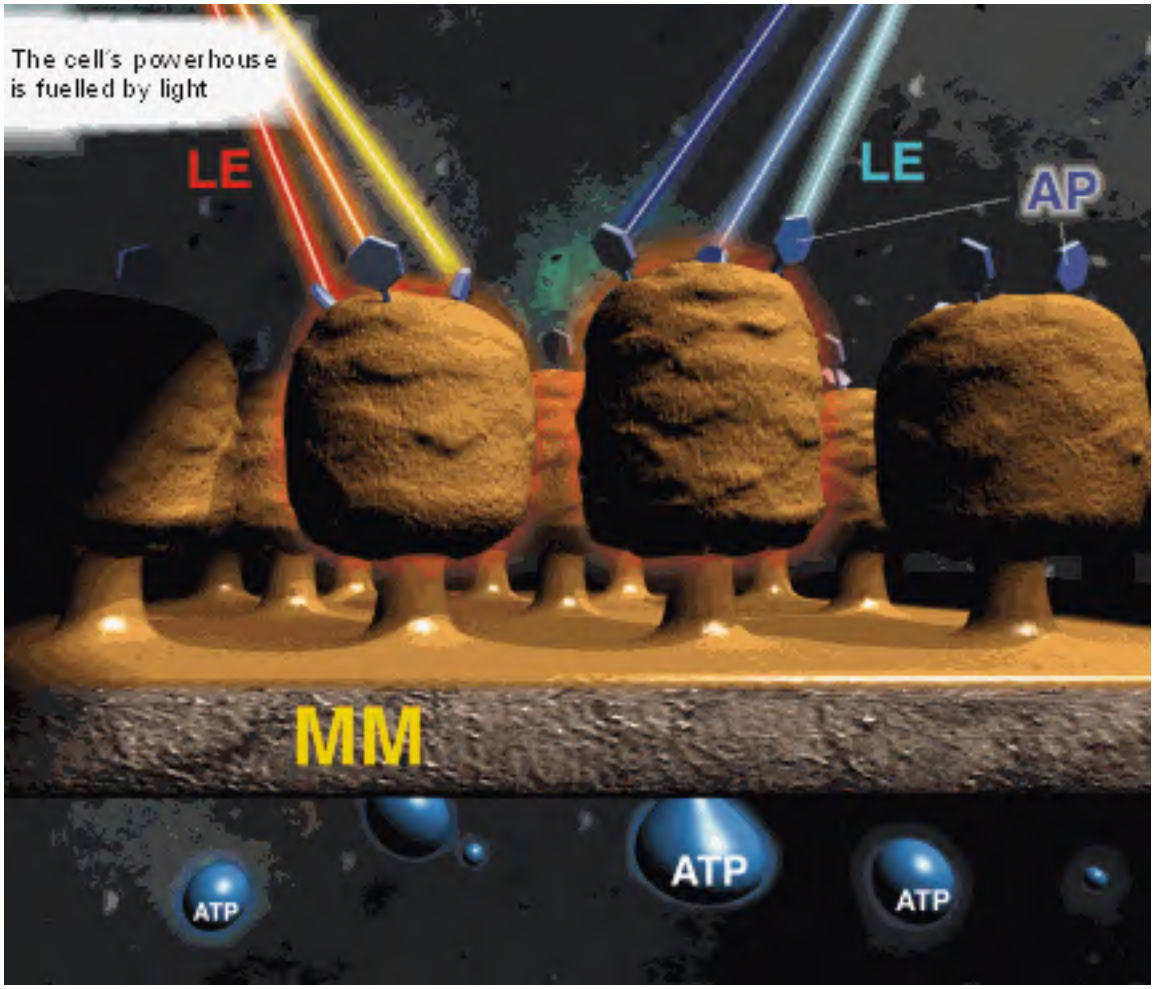

Fig. 5. The molecular bond energy (LE) irradiating the inner mitochondrial membrane (MM) is absorbed by the latter`s molecular structures (AP=antennae pigments) and utilized for the synthesis of ATP

How does low level laser radiation (LLL radiation) act on the cellular energy transfer?

The correspondence between the absorption energies of the cellular electron donator and acceptor systems with the energies released from chemical bonds (table 1) goes to show that – depending on its energy (frequency or wavelength) - an electromagnetic radiation (LLL radiation, for instance) irradiating the mitochondrial respiratory chain can be absorbed directly by the electron-transport systems and electron-carriers to be found there. In this context, the effective energy range comprises the whole visible region and also stretches to the near ultraviolet respectively infrared. Besides, oxidative phosphorylation in the cell is made possible by the steric combination of electron-carriers with protein molecules. The proteins guide the electrons through the respiratory chain so that they pass along from one enzyme complex to the other in the right order, a process that is effected by allsosteric rearrangements in the proteins involved. The electron-guidance system and the provision of energy for such dynamic conformation changes or vibrations in macro-molecules can not least be explained by LLL radiation as well. Taking into consideration radiation phenomena in connection with the mitochondrial energy transfer and electron flow, therefore offers new possibilities for a consistent interpretation of the energies released by the catabolism of foodstuffs and their absorption by the structures of the inner mitochondrial membrane. What is more, the effect of electromagnetic radiation (photons) in the form of LLL radiation on the mitochondrial energy transfer now can also

be accounted for, since this radiation is capable of stimulating macro-molecules, for instance, and triggering off geometrical and steric alterations of molecules and other components.

As has been shown by several experiments /15, 20/, electromagnetic radiation has a fundamental and immediate stimulative effect on cellular structures. For this reason, intensive research is being done to elucidate cellular stimulation points and the action complex of the electromagnetic radiation`s immediate stimulative effect in connection with the components of the respiratory chain, which can be understood as antennae pigments (see figure 5).

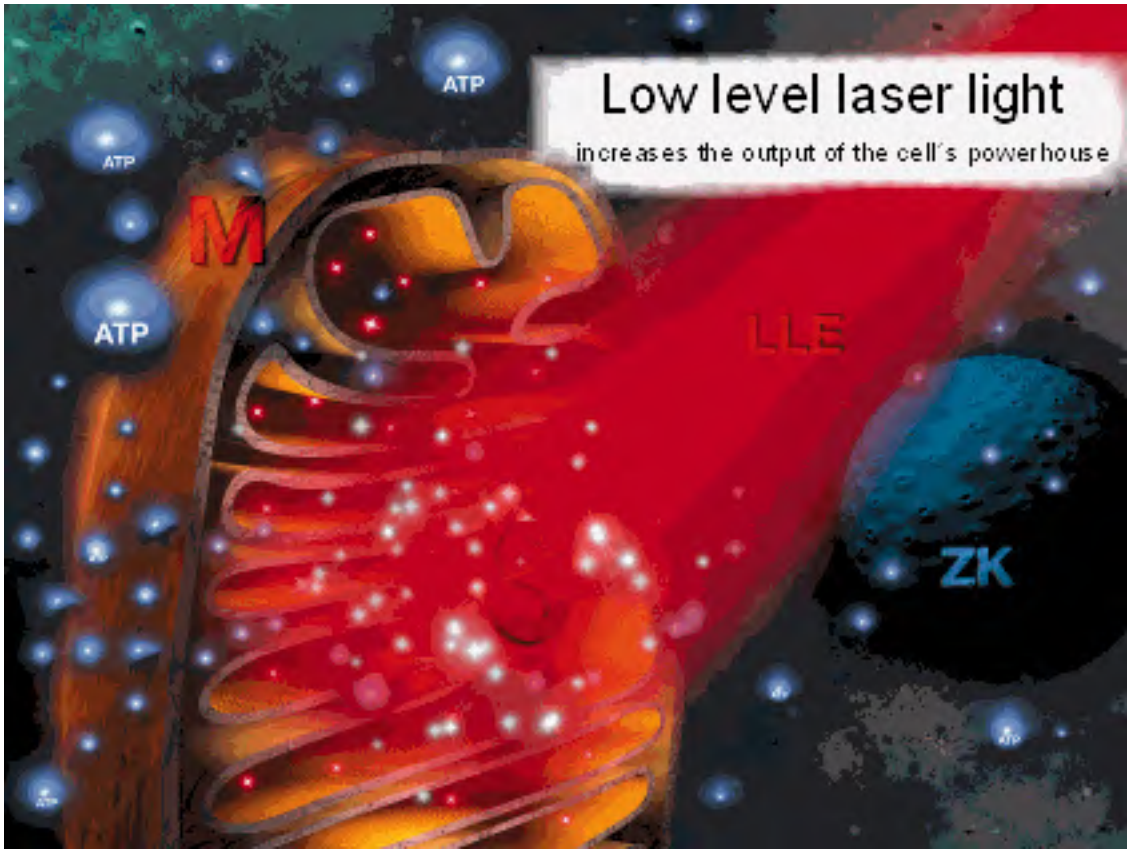

Fig. 6. Representation of the immediate stimulative effect of electromagnetic radiation (LLE = laser light energy = LLL radiation) irradiating the cell from outside

As there are many publications on the stimulative effects of electromagnetic radiation in the form of LLL radiation on man /3, 12, 16, 17, 18/, it is well known that these effects are on no account thermal /19, 20/. Variations of the energy of electromagnetic radiation go to show that proof of the effects of laser light on cells can only be established in certain frequency ranges. In this context, the wavelength (energy) region of electromagnetic radiation between 600 and 850 nm (red spectral region) seems to be particularly efficient /16, 19, 20/. LLL radiation from the red and near infrared region corresponds exactly with the energy and absorption levels relevant to the respiratory chain. This indicates that LLL radiation directly stimulates the components of the antennae pigments of the respiratory chain and thus effects an immediate vitalization of the cell by increasing the mitochondrial synsethesis of ATP. This kind of stimulation can bee seen as a biological resonance effect /21/, the components of the antennae pigments (electron-carriers) being resonators of different size and form, which resonate with a specific wavelength (energy) of electromagnetic radiation and can utilize the energy of the radiation in a functional way, that is, convert it for regulation procecces

in the cell. Figure 7 shows the correlations between the energy ranges relevant to the cell, given in wavelengths of electromagnetic radiation.

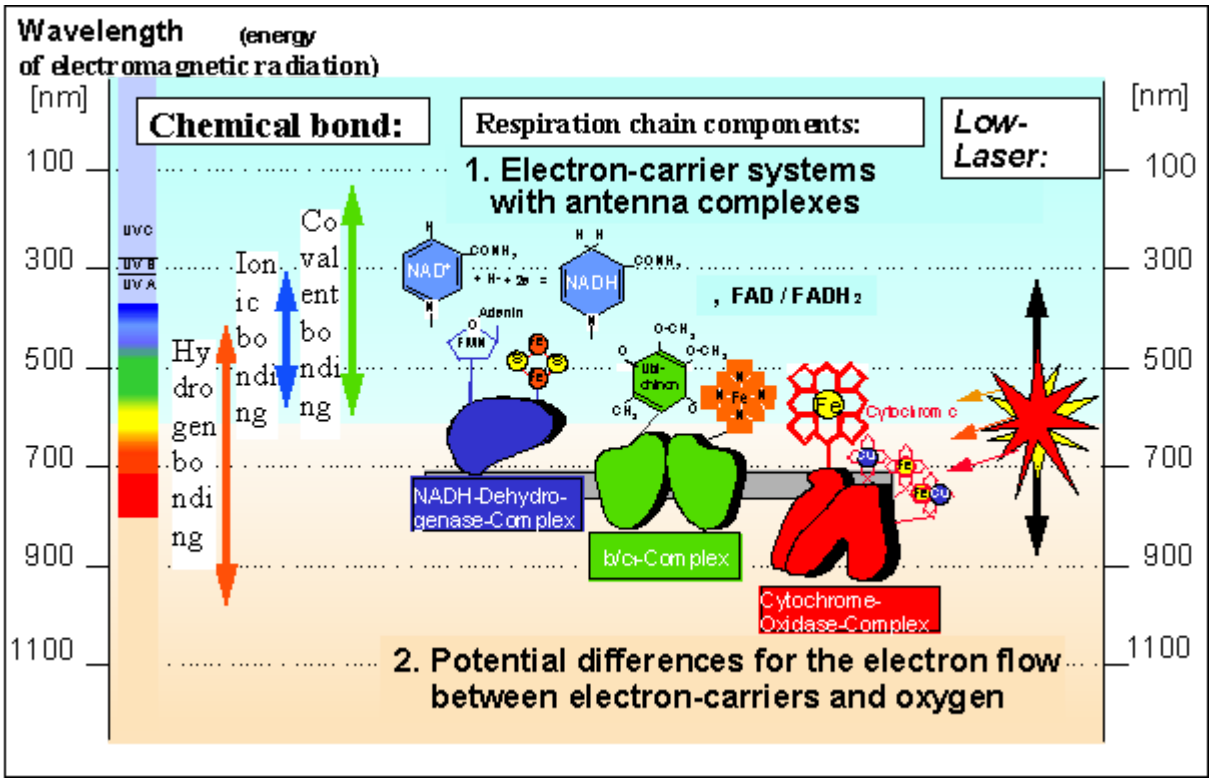

Fig. 7. Comparison of relevant energy ranges given in energy values of electromagnetic radiation between chemical bonds, components of the cellular respiratory chain and LLL radiation

Conclusion

On the one side, there are the characteristic energy contents of the chemical bonds as shown by table 1 that are released by means of the cellular catabolism. On the other, we find the absorption bands of the mitochondrial components of the respiratory chain - especially those of the electron-carriers with their antennae pigments listed in table 2 – which keep within the same energy level. These relevant energy ranges correspond remarkably well with the therapeutically utilized energy range of the electromagnetic radiation of LLL radiation and thus explain the positive influence of LLL radiation on cells as well as the biostimulative effect of natural solar radiation on heterotrophic organisms.

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