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An Electronically Driven Instability: The Living State (Does the Room-Temperature Superconductivity Exist?)

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Abstract: Considerations on the living state are given from the point of view of the collective electronic structure. An electronically driven instability has been observed, which is similar to the superconductive microscopical process. The life as a dynamical frustration is discussed. The possible room-temperature superconductivity is suggested.

THE ESSENCE OF THE LIVING STATE is a constant enigma for understanding. Different levels of thinking have given different answers in a wide range of transcendent and scientific fields. There are various religious, philosophical, biological, mathematical, chemical, and physical explanations existing. I have collected some microphysical considerations connected with the microscopic dynamics of the living state. My explanation is based on some new scientific results on the cluster-formation and high-T_c superconductivity.

The living process

An essential phenomenon of the living state is its extremely sensitive interaction with the environment: the ability of quick and differential reactions as a response to the outside effects. The physiological reply to stimulations is logarithmical (Weber-Fechner rule). The consequence of this rule is that the relative change ($\Delta I/I$) of the intensity of the incident primary (stimulative) effect, is constant; the change of the reaction intensity in living system is proportional to the intensity of the primary action. This special rule is an inherent behavior of the living sensors. The other, peculiar property of the living systems is local

stability or metastability under a wide range of the physical and chemical parameters. The definite circumstances satisfying the requirements for life are more and more limited by the complexity of the living body. For example, there are bacteria able to live between extremely large temperature differences, while the human life exists only in a very narrow temperature ($\Delta T/T \cong 0.016$) range. Furthermore, it is characteristic that the energy changes in all the life-processes do not exceed the value of 1.5 eV; while the oxidation processes are in average in the range of 12 eV. Consequently the living state has a limited change of relative reaction energies ($\Delta E/E \cong 0.125$).

How the sensitivity on life could originate from the living matter?

The living body as well as its smaller but unbelievably complicated units: the living cells are extremely complex systems. It is unlikely, that these massive units themselves could present such flexibility in their responses as we observe in living state. The cells are so intricate and interwoven that a considerable 'inertia' in their responses has to be expected.

The smallest microscopical functional units are the proteins. In the point of view of living sensitivity the protein structure and its interactions are still very complicated. The protein itself is so complex, that its characteristic high sensitivity and reactivity *in vivo* can not be expected by this massive arrangement.

The living system must be regarded as unit (1), its properties can not be additively composed from the properties of its parts, and it is not possible to divide it into the parts carrying the properties of the whole system. The living reactions are special processes which cooperative, collective phenomena expanded to the whole living unit (protein, cell etc.), depending on the level of the interaction. Some synchronized effects characterize the life (for example the growth or the dividing of cells etc.), which have to have a general controller in the system; but till now such chemical and/or physical parameters have not been observed. The cooperativity of the living state however is the essence of the phenomenon. I suggest, the central problem to understanding life lies in its collectivity and cooperativity. In this paper I try to explain how this cooperativity can exist *in vivo*, based on the different chemical and physical processes.

The cooperativity of the life process in a phenomenological chemical point of view is manifested in a complex and regulated oxidation process. The living body is only a 'furnace' where this process occurs slowly and well controlled. A chemical reaction with oxygen is occurring with materials (food in general) very slowly in a self-regulated way. The uncontrolled rapid oxidation process is a real burning, which no living state can sustain. Furthermore the uncontrolled process causes an impulsive energy-load of the living system raising the problems of energy-storage and energy-distribution. The oxidation — as an electron-transfer from the given material (electron-donor) to oxygen-atom, (electron acceptor) — regulated by the control of the charge-transfer. Very simplified, the living process itself, in the chemical point of view, is a highly organized control on the charge-transfer of the material incorporated by the system to 'burn' in the presence of the oxygen. An uncontrolled burning quickly consumes the energies in its near vicinity and the relatively localized burning body has no possibility to continue the process. The life with the regulated oxidation has developed a sophisticated chemical energy accumulation. The accumulated energy is slowly dissipated by oxidation, and part of the energy is turned into mechanical energy with the help of a special converter: the muscle. The life in this way destroys the

localization in space and the mobility of the system has to appear. The mobility of the living system has rendered possible the spatially non-limited amount of materials to 'burn.' The electron, transferred under definite control through the living system, has lost its potential (chemical) energy and lastly creates a liberating energy for living, and materials which cannot be oxidized further in the living process. This process is the base of biological metabolism, providing the energy for sustaining the living state. Water is one of the oxidized materials (the final product) which has the lowest energy among all the materials involved in the life processes.

The more sophisticated living bodies have a more stable accommodation to the different environmental circumstances. The living process becomes more independent from the environment; the life stabilizes itself. This chemical process makes possible life as a collective process, a dynamically stabilized instability (metastability).

Microscopical processes

Some cooperative mechanisms were introduced in the living state: chemical (2); solid-state electronical and ionic transfer (3); as well as the fractional charge-transfer (4). These considerations have had successes in the explanation of different special proteins (for example enzymes) or of the whole cell. For example an ionic concentration (pK) has been introduced (2) governing and explaining the collectivity of the processes.

The first suggestion of a solid-state electronic process as one of possible collectivity in proteins and DNA was made by Szent-Györgyi (5) in 1941. An early calculation (6) strongly suggested the existence of a conduction band in proteins. This was indeed proven experimentally (7), observing a semiconducting behavior with a forbidden gap of 2–3 eV (8). The measured conductivity in wet proteins (9) (there is no effect at all in dry ones (10)) supports this idea.

The kinetic theory of electron transport in biological processes is based on the so called solid-state concept (3). Not only the transport effects were explained as characteristically solid-type, but an electrical-mechanical cross-effect, the piezoelectricity, was also observed in the cell (11). These experiences were summarized in Szent-Györgyi's *Bioelectronics* (12). According to these bioelectronic ideas, the protein provides a background, (has a role of a 'stage' only) in the life processes, offering a special conductor for the information, and charge transfer. In this concept the flow of information is realized first of all by the controlled electron — (or more general by charge —) transfer. The protein *in vitro* is an insulator, their electrons are in the lowest possible energy, filling up the closed common electron-shells (valence-bands). The protein *in vitro* – in an insulating state — is not able to transfer any information and has only coupled electrons in almost localized bonds. (The protein *in vitro* has no ESR signal (13).) Due to the inert protein the cohesion forces between these molecules are not large; the system can relatively easily decay. The protein *in vivo* is different: it has a strong ESR signal representing uncoupled electrons; it is a good conductor, having a common band with other proteins in the vicinity; the cohesion forces in this system are strongly enhanced in comparison to their *in vitro* state. Starting from these, we suggest a strong spontaneous charge transfer that is responsible for the living state, giving the possibility of a special type of collectivity and cooperativity in the system. A collective mechanism is expected, and the band-structure is one of the possible reasons for this. However, such band-structure which exists in semiconductors is uncertain in these living,

large organic 'solids'. There is no long range order for creating a real electronic band, moreover these materials are not solids by their phase, most of them are gels. In addition to the band structure collectivity there are several other possibilities for a collective conduction: the hopping mechanism, polaronic mechanism and different wave mechanisms such as the charge density wave (CDW), spin density wave (SDW) as well as other collective waves gliding through the material. These mechanisms are very common in crystalline and amorphous solids.

The hopping mechanism can create a quasi-free electronic transport (14). For the polaronic mechanism a phonon assistance is necessary, which in the case of a single protein chain (because of the extremely large molecules involved), has no meaning. The tunneling due to the relatively large barrier between the molecules is unlikely. The CDW is also realistic, but the SDW and other energy-transferring waves are not satisfactory for there is no real charge transport which is required for the complex step-by-step oxidation process as was described above.

The essential mechanism of life in this submolecular level, is the electron-desaturation of proteins by various reagents. The desaturation goes through the electron acceptors. The living process is realized in a charge-flow making the final oxidation through various steps by different reagents (oxidation process). The oxidation goes step-by-step transferring only a fraction of the electron-charge in one step. The mechanism of the charge transfer is the life itself in micromolecular level. The collectivity appears in the conduction chain of information between the protein molecules.

The protein molecules themselves are closed, intermolecularly non-interacting objects. They create a set of non-connected inert islands. The isolation of the islands is enhanced by the adsorbed water (3). The adsorbed water-cover *in vitro* (and also in cancer tissues) is almost randomly distributed on the boundary of the protein molecule, producing an insulating layer with large dielectric permittivity (15). These insulating islands make collective intermolecular transport impossible.

The living state is different. There is a smaller dielectric permittivity around the proteins because of the ordered adsorbed water (15), while much larger cohesion forces are observed (15). In the living state the strict isolation as well as the electronic saturation of the macromolecule has been lost (13), desaturated proteins do appear. The system being an insulator *in vitro*, becomes semiconducting *in vivo*. The desaturation is produced by an electron acceptor, turning away the molecule from the stable, static equilibrium. The stable non-conducting state has been destablized *in vivo* and the molecules try to stabilize themselves filling up their shells to an electronically closed, stable situation. The non-saturated macromolecules seek to reach their stable, saturated form. The molecules in the neighborhood of one which saturates itself, will be more unstable due to the missing charge. The charge change here can be very small, the electrons do not like a ball jump from protein to protein, but only a fraction of their charge can move in this process. This can be visualized by the standard quantum-mechanics where an electron is 'spreaded' between the atoms involved in molecules, compounds and alloys.

Seeking local stability is contradictory to the global stability requirements. In actual materials the local and global energy requirements compete with each other for evolving the structure observed. It is supposed, that their balance has a central role in the formation of the actual phase (16). The high electronic stability is connected with the perfect saturated state, which is incompatible with the loss of a small amount of charge due to the electron

acceptors which are responsible for the 'burning' in living state. On the other hand the long range requirements are opposite: the effective long range could be created only by the large correlation length, which requires non-saturated, well-interacting species. The momentarily optimal short range order cannot be frozen in, because its neighborhood becomes more instable by the stabilization of the given short range unit (protein). The incompatibility of energy minima of the short and long-range orders creates an unstable situation, the material has to be frustrated. The non-saturated proteins will satisfy the long-range requirements, but in the short range the seeking to the saturated situation will dominate, contrary to the global tendencies. If these short-range forces are favored in the whole system, no long-range order balancing would be possible. Life would then disappear.

The frustrated material has a set of islands in a non-equilibrium state, and the balance of the local and global stability criteria determine the real dynamics of the charge distribution. The seeking to the electronically saturated, stable local environment is the driving force for a charge transfer. A charge wave can be frozen-in if the local forces are strong enough to stabilize the cluster against the global (long range) stability requirements. If it is not so, then due to the frustration a locally stable cluster can travel through the material. This is a dynamic equilibrium, as a solution of the frustration effort.

The apparent contradiction of the local global stability requirements depends on the effective ratio of the areas of local and global arrangements. The ranges of the interactions (short-, medium- or long-range) can control the process, which depending on the effective interaction-length (correlation length) have to become intermolecular and/or intramolecular. The intermolecular interaction starts only at a definite medium-range order, which is the direct limit between the living and non-living state on the molecular level. For the long range interactions to insure the global stability, the energy requirements are very much limited because the material is not in the solid state, nor is it a band-structure, nor are any definite quasi-particles (as for example the quasi-Bloch states in amorphous metals (17)) existing. Only short range interactions would freeze in the charge-transport, starting some saturated proteins. The observations on the electric conductance and the colored homogeneous matter *in vivo*, point out a non-frozen-in system, so a medium range interaction is in action in the living state. This is the origin of the frustrated state. A sensitive balance of the effective interaction length stabilizes the dynamic frustration, which is, I suggest, the basic behavior of the life.

On the possible superconductivity in living state

It was very early conjectured that the superconductivity in aromatic long-chain molecules (18) is due to certain biological system based on the conjugated double bonds containing π-electrons, as stated by London (19). Furthermore a possibility of superconductivity was conjectured in DNA molecules at room temperature (20).

In the field of high temperature superconductivity the excitonic pairing mechanism (21) was basically in the center of thinking. On the other hand the polaronic considerations are also popular (22). Some experimental evidences for room temperature superconductivity of inorganic Al-C-Al sandwiches (23) as well as of several organic compounds (24) focused large attention on the topic. There were some observations of room temperature superconductivity in real biological substances (25). Furthermore the possibility of the Bose condensation-like excitation of coherent modes was also published (26). The susceptibility (27),

magnetic levitation (28), Barkhausen-noise measurements (29) and absorption measurements (30), and remanent magnetization measurements (31) all give evidence of the partially (fractionally) superconductive biological objects. It was a great effort to realize the dream of room temperature superconductivity by these materials. Later these experimental facts were forgotten because the superconductivity (which was believed as fractional) could not satisfy any demand of practical applications. The enrichment of the superconductive phase was not successful for these materials, the transport superconductivity has remained only a dream.

The unsatisfactory status of these experiments is explained by the fact that this 'fractional' superconductivity was only intramolecular. The intramolecular superconductivity can be explained in these extremely large and complex molecules by the previously mentioned idea of London (19) and/or by the so called lone pairs (32), but for the intermolecular superconductivity one had no explanation at all.

Based on the dynamic frustration of the living state, I suggest, that only the 'particles' having Bose statistics provide the transport in living situations. If we suppose, that any current which is responsible for the information flow in living matter is based on particles having Fermi statistics, then the new states required to receive the incident intensity must occupy higher and higher energy levels, requiring higher excitation energies. This contradicts the Weber-Fechner rule postulating that the intensity of information flow depends only on the intensity of the simulating effect and does not depend on its energy in the living state.

Consequently we suppose that the transport in protein-chains is realized through the bosons (Cooper pairs) as in the superconductors. The pairing, the attractive interaction between a couple of electrons, has in its essence a very similar mechanism as in Bardeen-Cooper-Schriffer (BCS) theory (33). The pairing of electrons in this frustrated system is mediated by the collective motion of the locally stable clusters travelling through the living material. The pairing is based on the instability due to the vicinity of saturation. In a very simplified picture the pairing of two electrons is created as follows: An individual electron almost saturates the protein. This situation affects the next electron with too small kinetic energy (large effective mass) and for this reason can be easily captured by the stable short range arrangement. Due to this pairing, a growing instability appears and a wave of this situation will be gliding through. These travelling waves have to couple the electrons into pairs, satisfying the experimentally observed requirements described above. This pairing mechanism corresponds to the BCS with the only difference being that instead of the (virtual) phonons a non-harmonic instability mediates the coupling by the (virtual) 'breathing' of the local arrangements.

At this point it has an analogy with the newly discovered ceramics of high superconductive transition temperature, where the cluster-frustration mechanism could be responsible for the pairing (34). Furthermore in this sense cancer (where the intramolecular superconductivity is dominating), is a special process, reproducing the internal superconductive loops in individual molecules or isolated islands; being more and more isolated from other regions, as well as having less and less cohesion. The cohesive forces in the cancer-tissues are much less (consider the rapid distribution of cancer-defected parts) than in the healthy ones, indicating the inert, isolated molecules in cancer. The collectivity, the intermolecular charge-transfer and therefore the dynamic frustration is suppressed. This type of thinking

has been suggested on the other basis earlier (35), and is also consistent with Szent-Györgyi's suggestions (12, 36).

As a general conclusion to the ideas above we are suggesting that one of the essential phenomena of the living state is the superconductivity.

There are a number of experiments reproducing these special charge transfer processes and the intermediate stages in living process. Most of them can be followed by monitoring their special colors (4). Most charge transfer complexes are colored. *In vivo* the color characterizes the properties of the proteins. The charge transfer (the step-by-step oxidation) goes through a chain of free radicals. The break in the information- (oxidation-) chain of the living process is suddenly observable in the color change of the material. The frustrated living matter is colored. For example the liver in the normal living state is dark brown, while the liver-cancer can be recognized by the light green-yellow color of the cancer defected liver tissues (13). The HTSM ceramics which have good superconductive properties are also colored in the visible light, being dark yellow (37). The investigation of this phenomenon is now in progress.

Conclusion

A possible explanation of the life-processes has been suggested on the electronically driven frustration in the chain of proteins. The collectivity and the fine balance of the living dynamic equilibrium can be explained by these ideas. It may be a possible model for the room temperature superconductivity, and can explain some peculiarities of the living state.

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