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A Research Project on Living Matter

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It is widely agreed since long that living matter may be described and understood by physical and chemical knowledge. Living matter has a few essential distinctive notes, as follows:

1.It consists of various chemical species, organized in large molecular structures; the basic thermodynamic phase of these supramolecular structures is a non-uniform, inhomogeneous quasi-liquid, in non-equilibrium; the matter flows inside the living organisms, as provoked by the exchange with the outside, lead to the thermodynamic equilibrium in the end, during the life of the organism, until the death sets up.

2.It possesses a certain restricted variability, or relaxed stability, which suggested the "aperiodic crystal" hypotehsis; indeed, the electron energy levels in a periodic, infinite crystal are grouped into energy bands, separated by each other by energy gaps; the external factors, like electromagnetic radiation, may bring about transitions across these energy gaps, which would lead to permanent changes, or mutations, in the living organsims, and, therefore, to instability. On the contrary, a finite, relatively small (tens to billions) number of atoms organize themselves in small bits of solids, called clusters, where the electron energy levels are separated by larger energy gaps, and consequently, they are more stable with respect to the aggression of the external factors.

3.It possesses the hereditary, or reproductibility, character, localized in the DNA (dezoxirybonucleic acid); the DNA is a huge supermolecular aggregate, of a circumvoluted chain-like structure, localized in the nucleus of the living cells; it is divided into 27 chromosomes (for humans), each consisting of molecular sequences called genes, which, in their turn, are certain successions of four bases. This genomic structure may replicate itself during the growth process, while evolving to a quasi-equilibrium state, where the replication stops, according to the original non-equilibrium impetus received during the birth. The post-growth evolution of the organism continues up to the final equilibrium state of the death. All the vital functions slow and stop successively during the life, by a similar mechanism of gradually approaching the equilibrium.

The present Project of Research advances a new hypothesis, according to which the living organisms consist of a "clusterized state of matter"; this assumption allows to understand the above-quoted properties of the living matter in a unified manner, giving consistency and universality to our knowledge of life.

The assumption of the "clusterized state" of the living matter is based on a recent work[1] on atomic clusters. It has been shown in this work that a number of atoms may bind together to form a stable ground-state, as well as metastable shape isomers, in various geometric forms; some of these forms are highly symmetric, and they are associated usually with more stable clusters, called "magic" clusters.

First, one may notice that such clusters are finite micro-objects, therefore "aperiodic crystals" with point-like symmetries, as noted in #2 above. The electron energy levels will be separated by higher energy gaps as compared with bulk crystals, and one of the main objectives of the present Project is 1) to investigate the electronic structure of the atomic clusters. This investigation may proceed by solving Schrodinger's equation for electron motion in each ion potential, and applying thereafter the usual method of linear combination of atomic orbitals. Having got this way a precise knowledge of the clusters electronic structure, one may then assess the degree of stability-variability of such clusters with respect to the perturbational external factors, by estimating the response to external perturbations and the transition probabilities in various scattering processes.

Secondly, the existence of clusters shape isomers indicates that the inner cores of the clusters are practically unchanged, like very small bits of solids, while their surfaces fluctuate, and are statistically distributed, like a fuzzy liquid. This is obviously a new state of matter, whose properties are largely unknown, and the present Project aims at investigating the physical characteristics of such quasi-liquids. Consequently, another main objective of the present Project is 2) to characterize, by standard methods of the statistical physics, the extension of the fuzzy surfaces of the atomic clusters, their thermodynamic properties, the effect of these surfaces on the electronic structures, in order to assess the degree of chemical reactivity, and, therefore, of forming up larger clusters. It is worth noting that a continuous exchange of matter may proceed between neighbouring clusters, with a certain rate (to be determined), which is consistent with a non-uniform, inhomogeneous phase in non-equilibrium, of "clusterized matter", as noted in #1 above for one of the basic characteristics of the living matter.

Thirdly, as shown in Ref.1, the up-today investigations indicate that the atomic clusters have the tendency of getting together, at various rates, according to their size, symmetry and reactivity; this corresponds to the general principle of minimal energy, and reflects the approach to equilibrium of a statistical ensemble originally at non-equilibrium. This process may explain the growth stop, ageing and, finally, death. The slight inter-molecular effective potentials identified in Ref.1 act over the life time of the living organsim, attracting the atomic clusters to each other, leading finally to very large clusters (or clusters of clusters), which resemble more likely a solidified state over large spatial extensions in the organism, this being the end of the life of that living organism. Of course, this death state is not yet the absolute equilibrium state, the corpse continuing its slow process of physical decay as a quasi-amorphous phase, over large lapses of time, until the final disintegration. However, the main processes of life at macroscopic scale are no longer visible, and this may be taken as a definition of death. Another main objective of the present Project is 3) to investigate the rates of various super-clusterization in the "clusterized state" of the living matter, in order to estimate the duration, or the lifetime, of various vital processes. The standard methods of aproaching such an investigation are provided by the theory of the physical kinetics, or the transport theory.

The existence of the attractive inter-atomic effective potentials acting between atomic clusters, as mentioned above, indicates the original non-equilibrium state of the living organisms, as at birth. By virtue of the action of these potentials, which leads on one hand to growth stop, ageing and death, as seen before, the replication process in the genomic structure may also appear too, on the other hand. From this angle, the birth, growing, ageing and death have the same physical origin, namely the internal dynamics of the "clusterized matter". Indeed, the law of increasing the entropy requires atomic clusters be formed in as close as possible identical forms, and as many as posssible, hence the replication process, on one hand, while the minimal energy requires the formation of clusters as large as possible, on the other hand, hence the organisms' decay.[2] Differentiation of the living cells is itself an intermediate process between the increase of entropy and the minimum of energy. It is worth noting that the replication process is a statistical process as described

here within the framework of the "clusterized state" of the living matter, which may allow for hereditary variability. The reproductibility character of the living organisms and their hereditary properties, as noted in #3, may consistently be approached, according to this discussion, by means of the "clusterized state" theory. Another main objective of the present Project is therefore 4) the investigation of the statistical character of the replication proces, reproductibility and the variability-stability character of the hereditary mechanism, as simulated by the statistical dynamics of clusters. The standard approach to this objective is the approach to equilibrium, especially under external peturbations. It is worth noting that external perturbations, like a continous exchange with the outside, slow down the rate of approach to equilibrium, but the exchange itself is not possible anymore once very large clusters start to prevail. Identifying the kinetic equations describing such processes belongs to this objective.

The work in Ref.1 deals only with rather small, homo-atomic clusters with model point-like valence orbitals of the ionic cores, treated within the quasi-classical approximation which leaves aside the quantal corrections. For starting to bear any relevance upon the living matter the work must be extended to include different species of atoms (hetero-atomic clusters), especially carbon and oxygen, as elements specific to living organisms, but also atoms with directional, spatial-structure valence orbitals, like sulphur, phosphorus, magnesium, silicon, etc. The extension to valence orbitals with spatial structure, and the quantal corrections leading to the electronic structure of the clusters are necessary prerequisites for the main objectives of the present Project. The investigation of the effective inter-atomic potentials acting between clusters is very likely the next-step prerequisite in this connection. Primarily, the investigation should be focused upon the cluster nature of the four bases in the genome structure.

According to the Project sketched herein life is the approach to equilibrium of a "clusterized state" of matter. The occurrence of clusters with "life" properties may very well proceed by chance. The above considerations seem not to touch upon the psichic properties of the living mater, especially the human psichic. However, by trial and error in chaotic and erratic movements, the living organisms may learn, learning being the reaction of the living organisms to external perturbations, aimed at preserving their consistency. Some learning is inherited, like vital instincts, through reproductibility, by virtue of the dynamics of the "clusterized matter", including the reproductibility itself, some other is acquired. Noteworthy, learning itself has a statistical character. Moreover, from this angle, conscioussness is nothing but the knowledge of the natural laws. Thus we are left to the origin and cause of the natural laws, which is another problem.

References

[1] L. C. Cune, M. Apostol, Phys. Lett. **A273** 117 (2000); Chem. Phys. Lett. **344** 287 (2001).

[2] Under this circumstance life may also be viewed as a continuous phase transition.