

Structure and Dynamics of Organisms in Environment

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The structure and dynamics of organisms in environment are discussed from viewpoint of their *electronic structure* and its interaction with environment. The starting point is an electronic structure of a *free atom* with electronic states grouped in the spatial electronic *shells*. The step-by-step population of the shells with electrons (following quantum rules) recreates all known atoms and *organizes* them into the *Periodic System*. In realistic environment, atom electronic states mix to each other and change their *spatial form* adapting to the environment. The same fundamental feature is also typical for electronic states of molecules and crystals where *the bands* of states are the counterparts of atom electronic shells. Following this fundamental approach, we propose and discuss an extension of the shell model for *cells and organisms* viewed as large molecules placed in the environment. The focus of discussion is on (1) transformation of spatial forms of atomic electronic shells in environment, (2) the *spatial location* of the shells in a cell or organism, and (3) the *properties* of a cell/organism related to its electronic state. The transition from the free space to the environment with *vertical orientation* (due to gravity force) and the ground plane (earth) transforms the free-atom spherical electronic shells into the shells of vertical beads configuration moving them into vertical locations from the ground plane up. The very first, most stable shell with the lowest energy becomes an *electronic core* of the cell/organism. In a cell, the core corresponds to nucleolus or nucleus. In an organism, the core may correspond to the *foundation* of spinal cord system; other shells form a vertical discrete architecture. The electronic *core* becomes an organism's *growth point* located near the ground plane. Under environment impact further shells get developed and filled with less-bound electrons of spatially-rich electronic architecture and enhanced capabilities to respond to the environment needs. The most external shell is located at the top of the vertical organism architecture and has the least-bound electrons; its electrons can easily interact to the environment's electrons and radiation. The shells build-up stops when a balance is achieved with the environment. The shells form an organism dynamic *infrastructure* directly interfaced to environment. The proposed vertical electron architecture has similarities with cerebro-spinal architecture of higher organisms and their behavior in environment. The implications for understanding the mechanisms of organism development and evolution are briefly discussed.

1. The Role of Environment in Shaping Electronic Structure

The electronic structure of atoms, molecules and crystals is a well-established area of quantum physics and chemistry which allows for understanding the structure and behavior of "inorganic" matter, and was/is a basis for 20-th century high technologies including lasers, semiconductor technologies, quantum sensors, etc. This conceptual framework also integrates electromagnetic (EM) processes since any change in the electronic structure gets accompanied with emission and/or absorption of radiation and in many cases the interaction between electronic states and EM waves is *coherent*.

While "organic" matter is the foundation of living nature, its current understanding in terms of biochemistry and molecular biology is quite limited due to missing electronic structure and EM aspects which may be critical in understanding the organism behavior in an active environment. That new dimension might open new opportunities in understanding organism dynamics in environment, the origin of diseases and their mechanisms as well as in the next-generation drug discovery technologies. This paper is the very first, conceptual step in this direction. Its focus is on electronic structure of cells and organisms and its dynamics in the EM-active environment as well as on how the electronic structure and its dynamics impact the structure and functions of organisms in environment. In sect. 2 we present the electronic shell model for cells and organisms and discuss the cell and organism properties that follow from that model. In sect. 3 and 4 we discuss the mechanism of incremental build-up of organism's structures. In the sect. 5 we discuss a number of examples and applications of the model, and in the Sect.6 - future plans. In the the forth-coming paper we will discuss the details and applicable models.

1.1 Electronic structure of atoms, molecules, and crystals

Atoms and environment

In discussion of cell and organism dynamics, electronic structure used to be left aside. Meanwhile life is fundamentally impossible without formation of chemical bonds and related to this metabolism dynamics which involves valence or red-ox electrons. Chemical bonding is a typical quantum phenomenon, a result of quantum interference of electronic wavefunctions of interacting atoms.

Electrons in atoms and molecules are universally organized into *shells* of various spatial forms and binding energies. A free atom has an electronic structure which is based on *electronic shells*, ring-like spatial structures refer to with quantum number $n=1,2,3,\dots$; within an n -shell, there are *subshells of various shape*; they are known as *s, p, d, f, etc subshells* and correspond electron orbital momentum $l=0,1,2,3,\dots$, respectively. Shells with maximal number electrons are *closed* shells and the corresponding atoms are chemically *stable*. The shells with less than maximal number are *open* and the corresponding atoms are usually chemically *active*. The atoms with minimal number of electrons in the external shell are typical electron *donors*, whereas the atoms with almost filled

shells are typical electron *acceptors* - two very different classes in terms of behavior. The shells can be viewed as spatial layers. Each shell holds only a certain number of electrons. The n -shells, in sequence from the closest to the furthest from the nucleus, hold the maximum of $2n^2$ electrons, that is, 2, 8, 18, 32, 50, 72, and 98 electrons respectively for $n=1,2,3,4,5,6,7$. For example, these are a few lowest shells and subshells: $1s^2 - 2s^2 2p^6 - 3s^2 3p^6 3d^{10} - 4s^2 4p^6 4d^{10} 4f^{14}$, etc. In this sequence, the binding energy of the shell electrons gets smaller and smaller, and spatial properties (shapes and their variety) get richer and richer. Highly excited atoms (for example, atoms H in open space) may have electronic states with n as large as 500-700. An example of flexible spatial forms can be seen [here](#) (the 9 electronic states of H atom in the configuration $7g$, with $n=4$, and $l=3$).

All nature structures are built from atoms, and the shell electron architecture is a *fundamental* property of atoms. It is a basis for *Periodic System* of elements, a build-up principle and classification of atoms based on their electronic structure. An atom size gets determined by the radii of its external electron shell and typically is less than 1 nm. In some media (e.g., polar liquids such as liquid ammonia) an atom (e.g., Na or K) electron orbital may have 10-100 nm size. In some metals as well as in superconductors (at low temperatures), electron orbitals may have a macroscopic size. Electronic shells of excited atoms in open space may have huge size for $n \gg 1$ ($r_n \sim n^2$). The interaction of excited atoms/molecules with the EM field, in particular, the *resonant* interaction may create relatively large-size and long-term electronic states. So, for molecules, crystals and organisms, the electron shell size needs to be *evaluated properly* depending on specific environment the particle is in.

In the *realistic* environment (as opposed to *free space*), two extra effects emerge: *vertical symmetry* (due to the *gravity force*) and *back/forward asymmetry*. They transform the *spherical* electronic shells into *environment-specific* electronic shells. Simplified example of splitting and mixing of H atom energy levels in the axial electrical field (Stark effect) is shown at **Fig.1**. [see [here](#)]. That is the *foundation* of the proposed *environment-specific* electronic architecture of cells and organisms. The environment of (almost) *spherical* symmetry is typical for 3D media such as sea/ocean and atmosphere. Moving of simple spherical species from ocean into other media such as ground (earth) caused further transformation and adaptation of the free-atom-like electronic shells to the new environment. That possibly was the cause for the emergence of asymmetrical organism *forms* typical for plants and animals. The emergence of back-forward asymmetry (relative to a vertical plane) for animals is due to their *relocation capability* which is not available for plants *fixed* at their locations.

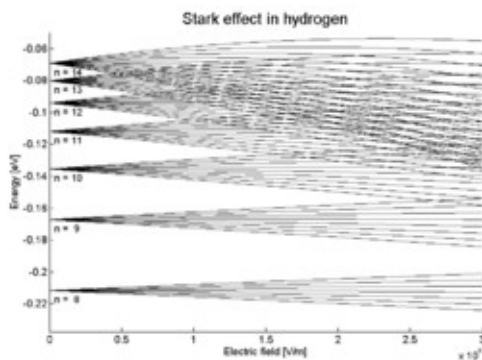


Fig. 1: Splitting of hydrogen electronic levels in the axial electrical field - [Stark effect](#)

Molecules in environment

Molecules basically have the similar *electronic shell* architecture, and can be described in terms of a *ground* state with tightly-bound electrons and *many excited* states of various spatial shapes depending on spatial configuration of the molecule. For example, benzene molecule C_6H_6 has an almost spherical ground *electronic state* (Σ -state) and many *excited* [Π]-states of various shapes with different nodal/dividing planes. Almost all said about atom electronic structure is applicable to molecules and their electronic dynamics.

Hellmann-Feynman theorem. The critical role of electronic state of a molecule/cell/organism is due to the fact that it is the electron state that *determines* a chemical reactivity and spatial arrangement of atoms, a kind of "hard copy" of the electronic state. Any change of electronic state *causes* a proper rearrangement of the atomic structure of the particle. So, the molecular rearrangements *follow* the change in the electronic state. This statement is the Hellmann-Feynman theorem formulated independently by [H. Hellmann](#) (1937) and [R. Feynman](#) (1939). We would also add that an electronic state is not only a *controlling template* for molecular architecture; it is also its *interface* to the environmental EM fields. In other words, the response of molecular structure to the EM field occurs via the molecule's electronic state. So, environmental EM field potentially is able to *change* the electronic state and therefore (via the Hellmann-Feynman theorem) *to control* the dynamics of molecular rearrangements.

Since chemical reactivity also depends on electronic state, the Hellmann-Feynman theorem is applicable to the process of attachment (and detachment) of new molecular fragments. For example, an excited electronic state typically has a "doubled" (relative to the ground state) shape with a nodal/dividing plane between two "halves". According to Hellmann-Feynman theorem, such a "doubled" electronic state drives a build-up of doubled molecular structure by *selective* attachment of the environmental components. This process is *universal* and transforms the environmental material into the copies of the "seed" molecular structure. In other words, life driven by the EM fields (from Sun and Earth) is supposedly designed to transform the environmental material into specific living forms with the seed (and its electronic state) as a mediator. In this process, the seeds compete in a massively parallel and distributed manner for environmental material. The observed "aggressive" nature of living matter ([Vernadsky](#)), its "unlimited" growth and propagation, may be related to this electronic dynamics. This feature of living matter has a fundamental geological meaning.

Crystals in environment

Crystals are built as 3D arrays of *elementary cells* each one with a single atom or few atoms, and their electronic structure also follows the mentioned fundamental rule: the ground shell/band with tightly-bound electrons and a number of shells/bands with less-bound electrons or unfilled by electrons shells/bands; the term 'band' has to do with the structure of energy spectrum of a crystal. Some crystals have certain properties similar to ones of cells and organisms, for example, [floating crystals](#).

We believe that the electronic structure of cells and organisms (being built from atoms and molecules) *can not* be based on totally different principles. Electronic states is a *fundamental* feature of matter, and so electronic structure of atoms, molecules, cells, and organisms should have similar *fundamental* properties if they are placed in similar environments. We also believe that *adaptation* (or flexibility) as the fundamental property of living matter can be understood only in terms of electronic structure that has a unique feature of *mixing* electronic states in new environments thus providing actually *unlimited* possibilities to build various shapes and forms (J. Bernal [B67], V. Weisskopf [W75]). The **Fig.1** shows mixing of various electronic states with the same energy in the simplest atom H. The applied electrical field violates spherical symmetry and introduces mixing (hybridization) of (many) states with the same or close energy.

2. Shell Model and Organism Architecture

2.1 Electronic structure of cells and organisms in environment

We extend shell model to the *electronic structure and architecture* of cells and organisms viewed as large molecules. The goal is to discuss how the electronic structure features allow for in-depth understanding the structure and behavior of cells and organisms, in particular, the properties not covered by standard biochemistry and molecular biology.

Similar to an atom, molecule, or crystal, the cell/organism shell model should include a core and higher shells. When placed in the environment with axial symmetry (gravity), the spherical architecture typical for free atom electrons gets transformed into electronic architecture with *axial symmetry*; the core shell located at the ground plane becomes the center of the growth from the ground plane up, a kind of foundation of the *growing* organism. The former free-atom ring-like shells become a part of *vertical beads architecture* with the highest shell similar to the highest (most remote) electronic shell in atom. This shell has the *least-bound* electrons and so this shell can most effectively interact with the environmental EM field.

The vertical architecture of the electron shells in the earth environment may be thought of as a *universal framework or infrastructure* of organisms with the shell/beads emerged due to interaction with environment. The shells with the *lowest and lower* energy are always *closed* ones (analogues of the closed *s, p, d*, etc shells in atoms), and their participation in cell/organism dynamics is generally *minimal*. The *open* shells, in particular, the most external one are active in metabolism and interactions with the environment. There are as well the empty, normally non-populated electronic shells (analogues of the lowest unfilled molecular orbitals (LUMO) and empty bands in crystals), which in some "pressure" or stressful situations may become partially populated and involved in organism dynamics causing significant changes in metabolism, brain dynamics, and somatic functions.

A cell/organism in environment also has an additional *mobility* aspect which may help to understand the plant/animal cell differences. Indeed, a *fixed* location of a cell/organism *limits* the interaction modes with environment and makes it local and dedicated. In contrary, a *mobile* cell/organism enjoys richer interaction mode which makes the cell/organism structure more generic and universal. Respectively, the size of dedicated plant cell may be relatively large, whereas the size of mobile and generic animal cell is relatively small due to availability of *variety* of the interaction modes. In fact, the sizes roughly are 10-100 and 10-30 μ , respectively for plant and animal cells - see details [here](#).

Electronic structure of a cell and its structural components. A cell - as any "large molecule" or *aperiodic* crystal [S44] - has a set of cell-wide electronic states. The *ground* state of an *unconstrained* cell usually is very much spatially *symmetrical* and compact, and its energy is separated from excited states by the *energy gap* which means a certain *stability* of a cell to any kind of noise

(within the gap). The excited states are usually spatially extended and may have sophisticated spatial structure depending on the specific electronic state and the cell immediate environment including EM field coupled to the excited electronic states; the coupling may create sophisticated *spatio-temporal patterns* of activities. The excited states always have one or more nodal surfaces that divide cell space into two or more compartments of various shape and temporal dynamics. Accordingly to the [Hellmann-Feynman theorem](#) applicable to any molecular structures, the change of cell/organism structure occurs via its electronic state so that the cell/organism's "hard copy" always *follows* the changes in its electronic state. An environment with *complex* spatial and temporal stimuli causes the corresponding changes in the electronic shells of a cell/organism, and each shell acquires a specific spatial architecture under environment control, in particular, the external shell/layer. Similarly to atomic *p, d, f, etc* electronic shells, the *higher* shells of a cell are more *flexible* and *rich spatially* and so may acquire a highly sophisticated *spatial architecture and temporal dynamics*. This also includes the contribution from environmental EM field which may *extend* significantly the cell size due to *coupling* with the external electronic states. These external, easily-bound electrons (shell) are involved in the metabolic processes (so called *red-ox* electrons), and so can mediate impact of EM fields. In contrary, the internal electrons form a dense, tightly-bound and highly stable *core*.

Layered growth. In the real environment the *core* shell becomes the most *close* to the ground plane and forms the infrastructural foundation of the growing multi-cellular organism. The general growth architecture driven by electronic shells can roughly be described in terms of three levels. The *endo-shells* is the core/stable zone of electronic infrastructure. The *meso-shells* are located in the "middle" of the organism's vertical architecture with the later in development layers/organs located at periphery of the organism. The *exo-shells* are located at the top of the organism vertical architecture and include the interface organs (eyes, ears) and signal storage and processing structures (such as brain's neocortex). In organisms, the limbs and similar relocation devices get developed "later" as *external*, purely environment-oriented facilities. Of course, within each macro-shell (tissue) there is a *fine spatial structure* due to the fine environmental features.

Cellular and multi-cellular electronic orbitals. Like the interacting atoms create molecules and crystals, the interacting cells create tissues and organisms. Like the atom's valence electrons are responsible for formation of molecules and crystals, the cell's valence or red-ox electrons are responsible for formation of tissues, organs, and the organism, in particular, their *responsive* layer/structure. In this process, atomic and molecular electronic orbitals (bands) get naturally transformed into cellular and multi-cellular electronic orbitals ("bands").

Like in the case of atoms and molecules, the *integrity* and *stability* of cells/organisms in environment is fundamentally due to the *discrete* nature of their *quantum states* (electronic shells) including the contribution from coupled EM modes. The valence electrons form the *cellular orbitals* which directly respond to the environmental challenges. Cells with *closed*, i.e. totally filled, electronic shells or bands are relatively *stable* (like noble gas atoms), whereas cells with *open*, i.e. partially-filled electronic shells or bands more easily interact with other cells and are sensitive to the environment impact. Likely, the muscle and bone cells/tissue can be thought of as an example of *stable* tissue, whereas the blood and lymph as an example of highly *mobile* and *responsive* tissue. In the *complex* environment, cell's electronic states get *mixed* forming *hybridized states* of specific spatial shapes adapted to the environment; this also includes a specific *temporal oscillatory* dynamic[W75], the one visible for example in neuronal axon dynamics. The *collective* electronic states/orbitals of tissues and organs, the *electronic densities and currents*, may be visualized as the *electrical* (or better electromagnetic) *framework* of the tissue or organ. Its *temporal* dynamics or *beatings* gives a possible explanation for *pulsations and rhythms* observed in organs as well as electron current/density traffic seen in the electroencephalograms (EEG), electrocardiograms (ECG), and electromiograms (EMG). A cell lowest energy electronic shell, an analogue of $1s^2$ -shell of atoms, is its *electronic core*. Its hard copy can be associated with the nucleolus and the nucleus. Cell's external electron shells/rings can be associated with the cytoplasm's ring-like structures such as organelles, endoplasmic reticulum (ER), centrioles, etc. Such states are very likely the *coupled* electronic/EM modes with flexible spatio-temporal dynamics. Similarly, the lowest organism electronic shell is its *electronic core*. Its hard copy can probably be associated with the lowest segment of the spinal cord system, the *coccyx* area.

2.2 Cell response dynamics

Signal dynamics. The proposed cell infrastructure introduces the *natural* signal dynamics similar to the one typical for large molecules and crystals. So, the signals are the *wavefronts* that are *coherent* and able to interfere forming an interferogram. Such a signal/stimulus from environment propagates to the cell core, gets modified by the core, and then propagates back to the cell periphery through the cytoplasm, where the signal triggers the *synthesis update* processes driven by the *joint* input from the core (genetic input) and the environment. Thus, within the proposed framework, *cells and organisms* get built-up *incrementally* by *populating* the potentially available electronic states within the fundamental electronic/EM shell architecture; the growth is a *response* to environmental challenge. The nuclear (genetic) contribution is also actively involved. The new external layers are built using the *selective* components supplied by the environment.

The growth creates *new* degrees of freedom and thus *expands* the adaptation capabilities ("plasticity" resource) of the organism to

the environmental challenges. Thus, the cell infrastructure and the environment create a *dynamic* (growing) framework within which the *search* occurs to find the cell states that *matches* the challenge [M83]. Since the build-up (growth) creates the new degrees of freedom, the search supposedly succeeds sooner or later (that is always successful). Thus, a cell/organism utilizes unique *growth logic* creating *on-the-fly* the plasticity resource to match the environmental challenge. With that resource, the *physical competition* between available states/modes (the physical trial-and-test process) guarantees finding the matching state; so, in a sense, it never fails unless the plasticity resource growth fails.

Generally, *simple* environments create *simple* organisms built around one or a few electronic structure shells. *Complex* environments create *complex* organisms built around many shells/layers. Thus environment *shapes* the architecture of the shells, and so the molecular structure of the organism. The build-up process is in *dynamic equilibrium* with the environment. It is *not* just a "genetically controlled" start, growth and stop; generally, life *dynamics* includes both *build-up* and *loss* of external layers, with the loss occurring when the environment gets *simplified* for some reason and so the current cell structure is *too complex* for the current environment.

Within the proposed model, the *genetic* component, the seed, is a *dynamic part* of that process. In its turn, the seed gets built-up gradually in the long-term, *phylogenetic time frame*. The cell's core build-up is due to the *almost-permanent* components of the environment, while the cell's *peripheral* elements are due to the *variable, novel* components of the environment - *changes* in atmosphere temperature, pressure, solar activities, etc. *Almost-permanent* components of the environment are still there - they though just *reinforce* the core (nucleus). Cell (expression) dynamics cannot ignore those long-term contributions, and they are not a "junk". As a whole, this is indeed, a flexible and smart *compression mechanism* of environmental signals, kind of *cell space division multiplexing*. This way a cell smartly encodes the environment dynamics saving its storage capabilities only for novel/important signals (and reinforcing almost-permanent ones).

Cell response structures and functions. In the active environment, a molecule undergoes an excitation of "valence" electrons with possible rearrangement of atoms and with following optional de-excitation. Which may occur by emission of photons and/or by relaxation via excitation of *soft* molecular vibrational and rotational modes. In cells, environment excites metabolic (red-ox) electrons which may cause rearrangements of the cell's internals and optional emission of photons (EM signals) to other cells around. The internal rearrangement, a response to the environment stimulus, may include a multi-step chromosomal rearrangement including separation and division. Like in molecules, the *anti-bonding* electronic states of cells - with the *nodal* surfaces - are critical for division and its dynamics.

Thus *red-ox electrons* directly interface environment and mediate jointly with appropriate EM field modes the cell response dynamics. That *coupling* of electronic and EM modes creates the cell-wide orbitals or modes that are the "front line" of the cell interaction with the environment. They sense changes and respond by *building* the proper structures and by *integrating* those into coherent architecture of the cellular response [M83].

DNA-driven model and its extension. The proposed model extends and complements the standard DNA-driven model by introducing a *multi-scale* (in space and in time) and multi-level *infrastructure* for an organism development in the *active* environment, an aspect of cell/organism dynamics that was very much neglected in the standard DNA-driven model. The DNA-driven model focuses on genetic information and its transfer between the various molecules such as DNA, RNA, and proteins. The proposed model focuses on the electronic/EM cell/organism *infrastructure* and its close relationships with the environment. The genetic information then comes in as a transferable *seed* and, in turn, gets built-up and updated as a result of the cell/organism interaction with environment. The seed is basically related to *geological*, large-scale time frame; in that sense, it is *not* quite a "pre-specified" control code, rather the result of accumulation of *long-term* inputs from the environment such as (slow) changes in temperature, pressure, atmosphere composition, solar activities, etc. Also, the DNA-driven model focuses very much on the protein synthesis control, a component of cell dynamics that does not say much about the spatio-temporal dynamics of cell functioning. The proposed model focuses on the cell infrastructure complementing the DNA-driven model with the infrastructural features.

The observed universal *layered architecture of the matter* can be naturally related to building the matter under electronic shells control. The tree annual rings, onion, cabbage, fish visible layered structure, and many other are examples of that universal infrastructure. Everything - solids, plants, animals get organized and built by their electronic shells control. From electronic structure viewpoint, an organism can be viewed as large molecule or *aperiodic* crystal coupled with EM field of the environment. The coupling with the environmental EM modes creates a *resonator-like* architecture with spatial structure of *extended size* and flexible temporal dynamics, so the framework (or infrastructure) becomes of macroscopic size - like in the case of crystals, where the atomic (nano-size) build-up creates in the growth process the crystalline structures of macro-size.

3. Incremental Build-up of Molecular Structures

The Build-up principle. We believe that fundamentally there hardly are *different build-up principles* for molecules, crystals, cells, and organisms - viewed as large molecules or aperiodic crystals. So, we formulate and discuss the build-up mechanism based on quantum properties of electrons in atoms, molecules and crystals, and apply it for analysis of the process of building molecular structures in cells and organisms. It is well-known the molecules are being built by *selective* attachment of suitable fragments to the molecular core according to the quantum rules of formation of chemical bonds. The Hellmann-Feynman theorem states that molecular rearrangements *follow* the changes in the electronic state. In environment, an electronically-excited ("doubled") molecular "seed" tends to *selectively* attach the proper fragments and thus transforms the environment's materials into its *own* copies, a kind of "aggressive" multiplication in the environment. The virus growth/multiplication is an example of that mechanism applied to transformation of cellular material into virus copies.

Atom-by-atom vs. layer-by-layer build-up dynamics

Layered built-up dynamics. Usually, a molecular structure build-up mechanism gets formulated in terms of *atom-by-atom* growth. The same is very much applicable to "biomolecules", where "an atom" gets replaced by a "binding site". For *macro* structures such as crystals involving a multitude of atoms, this is hardly a realistic mechanism: long time required for *sequential* build-up and strong *consistency* requirements for each elementary build-up step make that mechanism unlikely. Meanwhile, the crystal growth models [[details here](#)] are essentially based on sequential atom-by-atom growth, an option that seems to be quite slow. Theoretically possible massively parallel atomic growth model requires the attachment of billions atoms in-sync (simultaneously) and in spatially-organized manner, an option that seems to require a kind of *spatial organizer*. Recently [C05] the optical image control of massively parallel dielectrophoresis process has been demonstrated for about 15000 particles.

Therefore, we believe that for complex macro (bio)structures, the build-up process likely starts with preparing a *whole layer* rather than making it an atom-by-atom process. Within the proposed model, the preparation layer can be thought of as a hard copy of *spatial electronic shell* which is a kind of *spatial organizer* for atoms to be built-up into a layer. When a layer is prepared this way, it then gets *deposited as a whole* on the current core. In other words, the layered *electronic architecture* strongly suggests the *layer-by-layer* (that is, massively parallel) build-up mechanism vs. sequential one. Thus, we naturally come to the idea of a cell built by (ring) layers. A layer becomes a *unit* to build cellular molecular structures. The larger cells likely have more and larger layers than smaller cells. If a cell growth is a layer-by-layer build-up, not a *random* atom-by-atom process, the *coherent light pulse* is expected to be generated (as well as the acoustic wave) by *in-sync deposition/attachment* of each layer. This kind of layered mechanism of crystallization was investigated experimentally [B77] for growth of inorganic crystals, where the light pulses of less than 50 μ s were registered in sync with acoustic pulses. Similarly, cell dynamics may quite possible be a *coherent* process that generates the *coherent light* pulses and related *coherent* acoustic waves which could be used for diagnostic purposes.

A new layer build-up. When a *new layer* is being built-up, it includes a contribution from the environment *and* from the existing structure, so a layer *is* a physical *link* between these two components. Functionally, this is a *response* structure. The growth process is an *incremental* build-up of the cell or organism as a *sequence* of *linked* layers; it is *not* a single structure. Although a layer (e.g., a tree ring) *may look* like a separate structural unit, it is *linked or projected* into all other layers. To get access to the specific layer (in fact, to the response structure), a *proper* environmental signal/pattern *linked* to the response needs to be applied. So, a layer is actually a *distributed pattern* that physically links the specific environmental stimulus and the corresponding *response* structure.

4. Incremental Build-up of Organisms

Layer-by-layer growth of aperiodic living structures

Cell and organism dynamics is a challenging issue. The existing models such as kinetic ones describe quite well the temporal dynamics, they neglect though the *spatial* context. Questions such as what is the *unit* of growth, *what drives* the growth, and *when/why* growth gets stopped often are not addressed properly. We discuss a growth model which focuses on electronic structure and its interaction with the environment and introduces an *infrastructure* for understanding growth dynamics. The model views the living matter growth as a *layer-by-layer* growth of an *aperiodic* crystal, with each layer having a *variable composition*. Within a layer though the composition likely does not change significantly. The aperiodic structure can be described as:

$$[\mathbf{ctr}_1\text{-}\mathbf{B}_1] [\mathbf{ctr}_2\text{-}\mathbf{B}_2] \dots [\mathbf{ctr}_n\text{-}\mathbf{B}_n],$$

where $[\mathbf{ctr}_i\text{-}\mathbf{B}_i]$ is the *i*-th element of the 3D *aperiodic* architecture, which consists of the *control* part \mathbf{ctr}_i and body part \mathbf{B}_i . In an asymmetrical environment, the growth gets modified: quasi-spherical layers typical for free space get transformed into layers of specific shapes and composition depending on environment.

Growth, seed, and environment

Growth depends critically on availability of a *seed*. The seed is a *minimal core* to begin a doubling and propagation or growth. Growth process cannot start with a scratch: a "small" unit cannot be a seed. The seed supplies the growth process with the *unique* information. It includes a *generic template* of the organism to be built in the specific environment; it is *not* just "instructions" to build specific structure.

We believe that one component of that *unique* structure is likely related to the cell ability to *reuse energy*. This probably may be a critical element of what is known as life. A crystal needs a "nucleus" as a seed, and often a seed gets introduced artificially. A cell as a complex unit cannot *grow* without a seed. From viewpoint of electronic structure, and in particular, the Hellmann-Feynman theorem, applied to doubling of the existing molecule (seed), the presence of a seed is an obvious requirement of seed propagation.

Recently [L05], a method has been demonstrated for controlling the polymer crystal growth using dip-pen nanolithography and an atomic force microscope (AFM) tip coated with poly-DL-lysine hydrobromide. Triangular prisms of the polymer epitaxially grow on freshly cleaved mica substrates, and their in-plane and out-of-plane growth rates can be controlled by raster scanning the coated tip across the substrate. AFM images were concomitantly recorded for the growth process as it spans the nanometer- to micrometer-length scales as a function of environmental conditions.

Electronic excitation and growth. We assume that an elementary step of growth is related to electronic excitation of the core/seed by the environment. Then the excited electronic state, which is roughly a 'doubled' ground state, according to the Hellmann-Feynman theorem, drives the *selective* attachment of components which produce a 'hard copy' of the excited electronic state. Then, the next step works similarly but with the already "enlarged core" producing even bigger core and so on. On each step, the dynamics and architecture of the excitation is different as the current core is different as well as the environment input/contribution.

[Life is based on the idea of *unique* seed, a launch pad of the organism growth. Life is a propagation of the unique unit in space with (*re*)*configuration* capability. So, the *seed-driven* life is a way of unlimited and adaptable to the environment growth of molecular structures. The seed itself is more than just DNA. *Polymerization* does *not* need a seed, but generates an *unorganized* structure. *Stereoregular* polymers produced with [Ziegler-Natta](#) catalysts display a partially regular structure and use the catalyst surface as a seed to start a stereoregular structure/chain.]

5. Discussion

Integration of environmental effects. The proposed model builds on a universal mechanism of interaction of living matter with environment via the electronic shells. The basic step is the *incremental* build up of a *new layer* as a response to the environment challenge. For example, in the womb (as a challenging environment), an embryo goes through the stages of fish, amphibian, and mammals. This can be viewed as a sequential population of the higher electronic shells of ever increasing complexity and potentiality. So, the universal mechanism introduces an organism *layered architecture*, roughly the endo, meso, and ecto-layers that correspond to core structure of the organism, its connective infrastructure and the external interface layers, respectively. Each one though has also a fine structure due to the specific environmental interaction. The genetic component is always a part of the process: it modifies the synthesis and build-up and is being modified by the phylogenetic factors of the environment (phylogenetic history of the species), mainly by its *almost-permanent* components.

Lower energy shells contribution. Like in atoms, the core excitation requires a relatively high energy, in an organism, the core gets involved in the organism dynamics only under *strong pressure* from the environment. In this case, due to release of large energy and initiating powerful electronic currents, other shells get involved in organism dynamics - often, causing many unexpected and powerful phenomena such as the raising [kundalini](#). Due to its flexibility, the external shell usually establishes the *interface* with the environment. So, the common (regular) environment-driven changes are related first of all to the *exo*-layers of an organism, whereas the *meso*- and *endo*-layers and structures are used to much less involved, in particular, the endo core shell.

Organism tree, pair organs, and organ dynamics. Organism tree-like connected structure is a direct result of the *expression* of electronic architecture and is a *coherent* (in space and in time) growth and development of an organism in the environment. It starts from a seed that responds to its local environment and finishes when the organism loses its coherence and transforms back to molecular building components. In terms of organism architecture, the *pair organs* such as eyes, lungs, kidneys, ears indicate to a pairwise symmetry of electronic states of an organism relative to the left-right symmetrical vertical plane. The *hybridization* of electronic states and shells may also introduce more complex, e.g., four-lobe and multi-lobe architecture (see, the gallery [here](#)). For example, the pair organ eyes probably has an additional high-level pair - the third eye between the brows and the symmetrical fourth one on the back of head. Observed sometimes the 5-lobe growth patterns in plants can be seen as an expression of the *nd*-symmetry ($n > 2$) of electronic states; similarly, the 7-lobe patterns may be assigned to *nf*-symmetry ($n > 3$) of electronic states.

Within the proposed model, generally there is no notion of an *independent organ*, and an independent access to an organ (without violating its *dependencies*) is impossible. However, there is a *specific* input stimulus which *links* to the response *layer* that includes the organ; structurally, the response layer may not coincide with a separate organ. In fact, each organ has *projections or links* into all the other layers including the core. The links have *associative* nature. The whole mechanism of the layers build-up can be thought of as the "holophone" [Longuet-Higgins], a mechanism of temporal associative linking of patterns originally proposed to explain brain memory and its associative features. Later, the concept and the mechanism have been extended into space dimension and applied to build information and control systems based on associative access to data and actions [Bykovsky].

The ontogeny/phylogeny connection (recapitulation theory). The proposed model considers the development dynamics in embryo- and phylogenesis as "unfolding" process controlled by the *immediate* environment *and* by the growing core of the organism which begins with the minimal seed. The mechanism of transformation of external stimuli into layers is universal and applicable to both internal (ontogeny) and external (phylogeny) growth and development. Thus, internal and external development actually follow the same pattern because the principle is the same but the environments are different - embryo- and phylogenesis.

Biogenetic law (K.E. Baer): ontology repeats (recapitulates) phylogeny. In the growth process, the zygote is under intensive immediate control from the mother womb. The growth occurs until the embryo complexity is comparable with the one of the mother. After "rejection" by the mother, the external environment emerges as the new control system. The notion of evolutionary process covers "long" time and many generations; so, the *direct* comparison between the ontogenetic development and the multi-generation phylogenetic evolution is hardly possible. Meanwhile, during the growth in the environment, the new electronic shells of an organism get built up making it more complex and better fitted to the environment. At that stage, an organism transforms environmental material into *highly selective* growth layers. So, why at the ontology stage the development seemingly reproduces (at an accelerated pace) the multi-generation "evolution"? Well, the *electronic* interpretation indicates that the internal growth that starts from a zygote involves the same fundamental electronic shells/states mechanism. From that viewpoint, the recapitulation is an understandable thing: in both cases the same fundamental stages/shells/structures get involved in the growth. In addition, the complexity limit of organism growth becomes understandable: the number and complexity of shell elements of the organism electronic architecture is fundamentally limited.

Dynamics of gender. The electronic view of organism architecture allows for in-depth look into phenomenon of gender origin, sex and its dynamics in the environment. The gender used to be considered as *the permanent* feature of living creatures, existing *forever* and "*intelligently*" designed to implement the *reproduction* function. Meanwhile, an increasing number of observations during last few decades indicate that the phenomenon of sex in biological world seems to be much more *dynamic*. The analysis based on the proposed model indicates that the gender seems to *emerge* in the challenging environments and may *not be necessary* in other environments. The electronic aspects of organism architecture indicate that the possible origin of gender *phenomenon* may not be just a matter of reproduction. Indeed, in "relaxed" environments, the organisms probably had no "sexual reproduction feature" at all. This was a *generic* sex-free *proto-organism*. Yet, in the *constrained* environment, for example, if food is limited, a *single* proto-organism cannot *explore/search* the environment for food *effectively*. However, due to its highly flexible (electronic) dynamics, an original organism may transform under applied stress into two *complementary* "halves" each capable of *autonomous exploring* the environment for food or other resources. In other words, the challenging environment may *force* division of an original species into 2 or more autonomous parts which is *beneficial* in the *constrained* environment.

Being highly dynamic, the organism may operate as a set of autonomous units/parts when there is a need and comes back into the original *united* state when there is no such need. Such a flexible or "reconfigurable" organism has much better chances to survive. This feature though is not static and permanent. This is an example of *constraints-driven* dynamics and when the constraints get relaxed (or just gone), the feature may go as well. This discussion presents the gender/sex phenomenon as an environmentally-induced feature of an organism – of course, in long-term time frame. In the developed nations with the extensive life support ("relaxed" environment), indeed there were observed in last decades trends to the smoothing of male/female "extremities" and gradual development of mixed (gay, lesbian, etc) configurations.

Sleep and its quantum mechanism. Sleep mechanism was and is very much uncharted territory, although there are numerous observations of brain electrical activities during sleep and its various phases. We briefly discuss the aspects of sleep related to the electronic architecture of an organism. Any organism's electronic states get excited by light (daylight) and other perturbing factors in the environment. As in any molecular electronic system, there is a certain *threshold* of excitation, when the organism stops to respond to the external factors due to *saturation* effects. The saturation may mean the loss of an excited electron (ionization) with transformation the organism into a hard-to-excite positive core. That stage can be interpreted as a sleep, non-responsive stage. In awhile, the electronic excitation *relaxation* processes are set up which transform the excitation energy into various soft degrees of freedom. When the relaxation is basically over, the organism is ready again to respond to the environmental inputs, a "wake up" stage.

Due to its electronic nature, that mechanism is *universal*, and so *any* living unit in an *active* environment should have the sleep stage. Meanwhile, those excited states have much larger "radii of interaction" comparing with regular states. Then, due to enhanced

interactions with neighboring structures and the environment, unusual electrical activity (dreams?) may be evoked, sometimes with weird relationships due to highly enhanced and irregular interactions. According to the model, the active environments have to induce sleeping stage faster, whereas the inactive environments - slower. Any background perturbation also should stimulate sleep. Thus, the brain electrical activity supposedly should be maximal at the beginning of the sleep stage and minimal at its final stage. The known sleep pattern with the discrete (about 2h) sleep sessions can be explained in terms of discrete relaxation dynamics related to the few electronic shells involved in the relaxation process.

Advanced cell and organism dynamics: cell transformations in tissues/organisms. The electronic-structure-driven cell/organism dynamics makes natural various cell transformations that are difficult to understand within the standard "DNA-driven" approach that ignores the electronic and infrastructural aspects of cell dynamics.

Transformations during transitions between different media. Like some crystals (such as iodine) may directly release (or attach) atoms or molecules avoiding liquid state (so called sublimation), multi-cellular organisms (being fundamentally aperiodic crystals) may *release* into environment and/or *attach* cells. Of course, the sublimated molecules (or clusters) undergo changes in the new environment, including their electronic, vibrational and rotational states. Similarly, a cell released from tissue undergoes *de-differentiation* and then *re-differentiation* in the new environment. For example, skin cells in banana after piling it out, turn out to be in new environment (air) and supposedly should undergo de-differentiation and then re-differentiation in new environment (air) which may change drastically the cell behavior as well as its structure and functions/behavior. This phenomenon is essentially universal, so many *soft* tissues in vegetables and fruits may undergo this transformation and in some cases may change into very different cells. The cells released from banana soft tissue (after piling banana) may potentially undergo the transformation and de/re-differentiate in the new environment into cells "designed" to live in the air environment. Speculatively, one may think of such sublimated and re-differentiated cells as the "fruit flies". This phenomenon may have interesting connection to the stem cell structure and dynamics [C07b]. Indeed, for example, a skin cell being released from skin into "simplistic" environment, gets de-differentiated and stripped off its dedicated shells (and protein scaffolds) and then gets adapted (re-differentiated) to the new environment building up new *generic* shells and protein scaffolds corresponding to new environment.. Certainly, oits structure and *behavior* changes properly (and may be drastically) depending on the structure and dynamics of new environment.

Cell stability. Within the proposed model, the stability of a cell/organism in the environment fundamentally depends on its electronic state/architecture. As we have mentioned, cells with the closed outermost electronic shell have to be relatively stable in environment as all the cell-environment interactions in that state are *minimal*. Visibly, such cells have a distinct outermost ring in the cytoplasm, a structural counterpart of the outermost shell. An opposite case is the cells with the open electronic shell. They have a weakly-expressed outermost ring structure, and their interactions with the environment are relatively strong. For example, human embryo (or other) stem cells supposedly have such an electronic architecture and, accordingly, have a highly flexible functionality, that is, the capability to easily form rich structures and conformations suitable for tissues with missing or decreased functionality. Stem cells obtained in static and rotary suspension culture (see ref. [C07a]) are quite flexible. The lymphatic and blood cells can also be seen as that type of cells.

Organism stability and mobility. Similarly, the organisms with the *close* electronic architecture have to be relatively stable in environment, whereas organisms with the *open* electronic architecture have to be relatively active in their interactions with environment. In its turn, the electromagnetically active environment may populate empty/unfilled shells and thus create new open shells enhancing interactions with environment. So, speculatively, one can think of "geographically-induced" (in fact, environmentally-induced, including solar activity) effects of enhanced "openness" for human populations which would be active in exchanges, contacts, communication, etc.

Mobile vs. fixed cell configurations. (Micro)organisms with fixed location (attached to the ground) see quite stable and dedicated environment, while the *mobile* (micro)organisms see variable, more rich and generic environment. How this impact the electronic architecture and structure/functions of the (micro)organisms?

Electronic structure and "small" particles (viruses, bacteria, phages, etc). Cell is a relatively large and stable unit, but its excited states may split up various components, a counterpart of dissociation reactions. Similarly, small particles are able to associate into larger structures, a counterpart of association reactions. Another feature of small particles is their intrinsic increased *activity* comparing to a cell; indeed, the genomic component of a small particle, say, for a virus typically 1-100 Mdaltons, is a reactive unit with conjugated heteroaromatic rings, so it is able react actively (even having a protective protein capsid) ready to intercept red-ox electrons of cellular structures. From viewpoint of their electronic structure, small particles often have an almost-symmetrical shape and represent "bare electronic core" systems very active in environment.

Nanoparticle connection. The nanoparticles such as gold, copper, silver, CdS, and many other are examples of natural and man-made "atom-like" structures with active electrons organized into shells. Clusters M_n of n metal atoms with $n=10-1000$ have been

observed, including the highly reactive negative ions M_n^- . Being reactive, that is, having unfilled electronic shells, such particles may form complexes with proteins, in particular, protein layers (capsids) including antigen proteins. Since ancient times it has been known that metallic nanoparticles in the form of colloidal metals (gold, silver, etc) display distinctive anti-microbial, bactericide as well as stimulating effects on human body. This may be related to their electronic structure, in particular, to the presence of active *d* and *f* electronic shells (Au, Ag are *heavy* metals) with rich *d*- and *f*-spatial electronic architecture which can be easily involved in interactions with proteins; they also can strongly impact nucleic structures which have conjugated aromatic rings with heteroatoms. Those effects are lately widely used in so called "biobarcode detection" technologies [M06].

Allergy, hypersensitivity, etc. Normally, due to the quantum *selectivity*, a cell attaches *only native* fragments matching the electronic architecture of the cell's external shell. When a "foreign" body is present, it doesn't match the selectivity criteria and this triggers the *wide-spectrum* response of a cell/organism which is forced to handle "the novelty". Such a response creates many new *active* shells (the excited states). The result of such response to the foreign body is that the newly developed response structures (due to their wide-spectrum capabilities) can successfully respond to various structural problems. Those new architecture (new layers) form a kind of *memory* of that specific foreign body. Since the cell 'material' has the storage capability (soft modes), the memory effect still exists even after the foreign body is gone. "Hypersensitivity" is related to that memory effect and the hyper-effect is due to the already existed memory pattern that induces extra/hyper response to the same or similar "foreign" body.

Stem cells connection. A *specific* cell can be transformed into a *generic* one (stem cell-like) by applying the generic "simplifying" environment that would strip the specific cell off all its specific/dedicated shells leaving a compact generic cell ready-to-be-respecified in the new environment. Of course, depending on the *degree of specificity* the simplifying dynamics may vary significantly. Recent experiments [C07b] that used the viral vectors to introduce novel genes demonstrate this stripping effect. Meanwhile, such a "wet" technique being impressive may not necessarily be the best and very practical. For example, easy-to-apply and control EM fields may have the similar effect of stripping a cell off its specificity and making it a generic cell.

6. Conclusions and future research

The proposed electronic-structure-based framework introduces the language, concept and generic model which may help to better understand organism dynamics, a situation similar to how quantum dynamics of electrons in atoms and molecules has already provided an in-depth understanding structure and behavior of atoms and molecules in terms of their electronic dynamics. That in-depth understanding has laid a foundation for advanced quantum technologies of 20th century - lasers, quantum etalons, detectors and memory elements, optical and silicon technologies. So, there are certain reasons to expect that an in-depth understanding of electron structure and dynamics of cells and organisms would open new dimensions in the next-generation "organic" technologies.

We summarize our findings as follows:

- structure and dynamics of cells/organisms is likely due to their electronic shells/layers, counterparts of atomic electron shells transformed by the specific environment into highly specific shapes and forms; they form a dynamic *infrastructure* of a cell or organism
- the interaction with environmental EM field *couples* the electronic and the environmental EM infrastructure into the *integrated* infrastructure – the foundation of cell/organism dynamics in the environment
- *integrity and stability* of cells and organisms is due to quantum nature of shells/layers
- *growth* of organisms occurs by layers/shells in discrete manner by recycling materials of environment in the manner which can be thought of as a kind of *periodic system of organisms* based on their electronic structure taken in its interaction with environment
- each build-up layer is a *response unit* that is related to specific environmental stimulus; the response unit may have projections into other layers, responses to the stimuli related to this one
- the layer build-up is an *in-sync, massively parallel* process driven by the proper electronic shell
- an access to a specific function is possible only by applying the proper stimulus, the one used when building the response unit; thus, "slicing" a cell into units can be done by applying proper stimuli ("associative" slicing), and each such unit contains *many* genes; a *location* of a specific structure does not mean necessarily a specific function

- although an organ looks structurally like a standalone part of the organism, it is not the case; its removal impacts the whole chain of the organ's *dependencies*; so called pair organs are in particularly highly dependent on each other
- the *cell nucleus* is a set of layers which is due to the *almost permanent* (long-term) factors of environment; they do not contribute much into protein synthesis but this is *not* a “junk”; for example, it responds to the thermal (and other) “shocks” by synthesis of *generic* thermal shock proteins
- the proposed model taken in geological time frame contributes into better understanding of the *origin of species*:
 - the presence of the *permanent core* and the local *variability* of environment creates - in species space - a generic organism (“genus”) and its instances – species developed as *expressions* of the local environment structure and dynamics
 - *generalization* capability of a cell substrate due to the stimuli spatial overlap makes a cell/organism a “compressing” biological sensor of environmental trends; for example, the past climate dynamics can be traced in the fine structure of rings in a cell nucleus of local species
 - life and its evolution can be seen as a “side effect” of the increasing ability to *reuse solar energy* developed as a result of *physical competition* of molecular structures for energy and material resources – kind of a “winner takes all resources” situation, which means a *selection* by growth and multiplication rather than by the fitness
 - the energy reuse process gets accelerated by the ability to transfer (“reuse”) the seed from the past generations without starting the growth from scratch

Future research. The proposed approach is the very first step in better understanding cells and organisms dynamics in environment. Further efforts are necessary to clarify (1) the dynamics of transformation of spherical electronic shells of a free atom into vertical discrete beads architecture of environment-constrained atom; (2) specific dynamics of responses of a cell and/or organism to the stimuli; (2) mechanism of integration of response units into cell dynamics and techniques to “slice” a cell into individual units and their possible use as the real “response genes”. In addition, the mechanism of layer build-up needs to be refined, including EM field modes integration.

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