Global Journal of Science Frontier Research: A
Physics and Space Science
Volume 22 Issue 6 Version 1.0 Year 2022
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Elivination of the Contradiction between Thermodynamics and Evolution

By Etkin V. A.
Togliatti State University

Abstract- The article proves the dialectical unity of the processes of evolution and involution in biological systems, due to the simultaneous flow of which the process of their "aging" slows down, and the duration of the reproductive period increases. The strengthening of the role of such "opposite" processes as the systems become more complex is the essence of the basic law of their evolution, which eliminates "the glaring contradiction of thermodynamics with biological evolution." A more general energy-dynamic theory of biosystems is presented, which takes into account their heterogeneity with the help of additional parameters of their non-equilibrium. The theory returns to thermodynamics the concepts of force, speed and power of real processes and supplements the theory of irreversible processes by taking into account the reversible component of real processes. The unity of energy conversion processes in technical and biological systems is proved. Simpler non-entropy criteria for the evolution and involution of biosystems are proposed for each degree of freedom inherent in it. It is shown that relaxation processes in some degrees of freedom of biosystems are accompanied by the performance of work "against equilibrium" in other degrees of freedom, which is the essence of the Darwinian "struggle for existence".

Keywords: thermodynamics of biosystems, evolution and involution, processes of relaxation and metabolism, bioenergetics and survival.

GJSFR-A Classification: *DDC Code: 536.7 LCC Code: QD504*

Elivination of the Contradiction between Thermodynamics and Evolution

Etkin V. A.

Abstract- The article proves the dialectical unity of the processes of evolution and involution in biological systems, due to the simultaneous flow of which the process of their "aging" slows down, and the duration of the reproductive period increases. The strengthening of the role of such "opposite" processes as the systems become more complex is the essence of the basic law of their evolution, which eliminates "the glaring contradiction of thermodynamics with biological evolution." A more general energy-dynamic theory of biosystems is presented, which takes into account their heterogeneity with the help of additional parameters of their non-equilibrium. The theory returns to thermodynamics the concepts of force, speed and power of real processes and supplements the theory of irreversible processes by taking into account the reversible component of real processes. The unity of energy conversion processes in technical and biological systems is proved. Simpler non-entropy criteria for the evolution and involution of biosystems are proposed for each degree of freedom inherent in it. It is shown that relaxation processes in some degrees of freedom of biosystems are accompanied by the performance of work "against equilibrium" in other degrees of freedom, which is the essence of the Darwinian "struggle for existence". The connection of the mentioned law of evolution with other theories of evolution is discussed and a conclusion is made about its correctness.

Keywords: thermodynamics of biosystems, evolution and involution, processes of relaxation and metabolism, bioenergetics and survival.

I. INTRODUCTION

Despite certain successes in studying the processes of evolution of living and non-living nature from the standpoint of nonequilibrium thermodynamics [1-9], bioenergetics [10-15] and synergetics [16-20], an obvious contradiction of not only classical, but also nonequilibrium thermodynamics the nature of biological evolution ”is preserved. Interpretation of the second principle as a principle of increasing entropy imposes “thermal death” on the Universe, and degradation on any of its closed parts [21]. Attempts to consider evolution as a random process [22], the result of the emergence of “order” from “chaos” [19] and even more so “consumption of negentropy” [11] did not give satisfactory results. The very concept of “self-organization” of systems, understood as a spontaneous (not imposed from the outside) ordering of the system [21], is in “blatant” contradiction with the principle of “self-infringement of equilibrium” of classical thermodynamics. Attempts to "explain" the emergence of anti-dissipative thermo-mechanical, thermochemical, thermoelectric, thermo-magnetic, thermo-galvanomagnetic, etc. effects as manifestations of "synergetism" - the superposition of dissipative processes [2, 3].

A way out can be found from the standpoint of a more general theory of transfer and transformation processes of any forms of energy [23], developed and supplemented later in the monographs "Thermokinetics" [24] and "Energodynamics" [25]. Unlike W. Thomson's "pseudothermodynamics" [25] or L. Onsager's "quasithermodynamics" [26], this theory does not exclude from consideration any (irreversible or reversible) part of the phenomenon under study and covers the entire range of real processes - from quasireversible to extremely irreversible. This is achieved by finding the driving forces of these processes Xi and their speeds (flows Ji), directly on the basis of the law of conservation of energy, generalized to systems that are far from equilibrium. This opens up new possibilities for the application of thermodynamics to the study of biosystems and eliminates its contradictions with the laws of biological evolution.

II. METHODOLOGICAL FEATURES OF ENERGODYNAMICS

The fundamental difference between energo-dynamics and thermodynamics of the irreversible processes (TIP) and other fundamental disciplines is its ability to consider nonequilibrium systems as a whole, without dividing them into an infinite number of elementary volumes *dV*, assumed to be homogeneous. This allows you to preserve the so-called system-forming connections inherent in the biosystem as a whole but absent in its individual parts. It is these properties that distinguish a living organism from a simple set of organs (subsystems) or mass elements that are formed during such fragmentation. In view of the inevitable disruption of the functions of individual organs when the organism is divided into volume elements, attempts to restore the system-forming properties lost at the same time by finding "suitable integrals" are doomed to failure. The realization of this circumstance was, according to A. Poincaré, “the greatest shock that physics experienced since the time of I. Newton” [28].

Author: Prof., Doctor of Technical Sciences, Togliatti State University (Russian Federation). e-mail: v_a_etkin@bezeqint.net

Another methodological feature of energy dynamics is taking into account the opposite direction of processes in different parts (areas, phases, components) of a nonequilibrium system, which makes such processes irreversible even when they are quasi-static (infinitely slow). This can be verified by selecting subsystems with volumes V' and V'' in a non-uniform object of study, within which the density $\rho_i=d\Theta_i/dV$of any extensive parameter of the system Θ_i (its mass M, number of moles k-th substances or phases N_k, entropy S, charge Θ_e, components of momentum P and its moment L, etc.) is greater or less than their average value $\overline{\rho}_i=V^{-1}\int\rho_i dV=\Theta_i/V$.Then, by virtue of the obvious equality $\Theta_i=\int\rho_i dV=\int\rho_i'dV'+\int\rho_i''V''=\int\overline{\rho}_i dV$we have:

$$\int(\rho_i'-\overline{\rho}_i)\,dV'+\int(\rho_i''-\overline{\rho}_i)\,dV''=0. \qquad (1)$$

Hence it follows that in a non-uniform system there are always subsystems (areas, phases, components) in which this deviation of $(\rho_i'-\overline{\rho}_i)$ and $(\rho_i''-\overline{\rho}_i)$ has the opposite sign. the law of "unity and struggle of opposites."

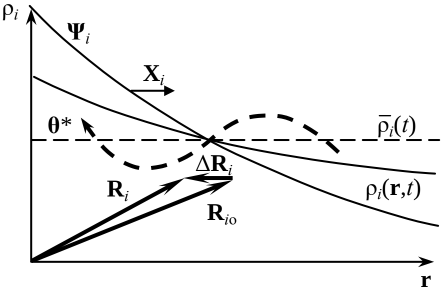

Figure 1: To the formation of the distributionmoment

Another methodological feature of energy dynamics is the refusal to use in the foundations of the theory of hypotheses, postulates, model representations and considerations of the molecular-kinetic and statistical-mechanical theory, including the hypothesis of local equilibrium by I. Prigogine, which lies at the basis of the TIP. According to this hypothesis, the volume elements of a non-equilibrium system as a whole are in local equilibrium (despite the occurrence of dissipative processes in them), so that their state can be described by the same number of variables as in equilibrium (despite the appearance of local "thermodynamic forces" X_i), and all equations of classical thermodynamics are applicable to them (despite their inevitable transition into inequalities). Contrary to this hypothesis, additional parameters of nonequilibrium of the systems under study are introduced in energy dynamics. The necessity of their introduction is proved by the "principle of definiteness", according to which the number of independent arguments Θ_i of the internal energy U as a function of the state of the system is equal to the number of independent processes occurring in it. This principle, which is proved in energy dynamics "by contradiction", requires the introduction of additional coordinates of vector relaxation processes that cause a "redistribution" of extensive parameters Θ_i over the volume of the system. To find these coordinates, consider an arbitrary system with an inhomogeneous density $\rho_i(r) = \partial\Theta_i/\partial V$ of any extensive parameter Θ_i, considered as a quantitative measure of the i-th energy carrier (Fig. 1). As follows from the figure, when ρi deviates from the average value, a certain amount Θ_i^* of the energy carrier Θ_i is transferred from one part of the system to another in the direction indicated by the dotted arrow. Such "redistribution" of the extensive value Θ_i causes a shift in the center of its value from the initial position $R_{io}=\Theta_i^{-1}\int\overline{\rho}_i rdV=0$ to the current one $R_i=\Theta_i^{-1}\int\rho_i rdV$. In this case, a certain "moment of distribution" Z_i arises:

$$Z_i=\Theta_i\Delta R_i=\int_V\left[\rho_i(\boldsymbol{r},t)-\overline{\rho}_i(t)\right]\boldsymbol{r}dV. \qquad (2)$$

with a shoulder $\Delta R_i=R_i-R_{io}$, called in energy dynamics "displacement vector" [25].

Since $\Delta R_i=0$in a homogeneous state, the state of the nonequilibrium system as a whole is characterized in the first approximation by a doubled number of state variables Θ_i and R_i, i.e., $U=\Sigma_i U_i(\Theta_i,R_i)$. In this case, its total differential can be represented as an identity [25]:

$$dU\equiv\Sigma_i\Psi_i d\Theta_i-\Sigma_i F_i\cdot dR_i, \qquad (3)$$

where $\Psi_i\equiv(\partial U/\partial\Theta_i)_R$is the average value of the generalized potential (absolute temperature T and pressure p, chemical μ_k, electric φ, gravitational ψ_g and other potentials); $F_i\equiv-(\partial U/\partial R_i)_\Theta$is the forces in their general physical understanding as a gradient of the i-th form of energy with the opposite sign, the specific value of which $X_i=F_i/\Theta_i$corresponds to the concept of thermodynamic force X_i in its "energy" representation [29].

The members of the 1st sum in expression (3) are in conditions of constancy of ΔR_i, that is, in the absence of redistribution processes. This means that the local potentials ψi in such processes change to the same extent in all parts of the system (as well as in homogeneous systems). This kind of change in state is reminiscent of a uniform fall of precipitation on an uneven surface. Their particular case is the equilibrium (reversible) processes of heat and mass transfer of the system, the work of introducing k-th substances or charge into the system, its all-round compression or expansion, etc. do not determine the heat or work of the process, as was the case in the case of reversible processes. On the contrary, from the very beginning it is recognized that the variables ψ_i are emergent quantities, that is, they can change in the general case both due to external energy exchange and due to internal sources during the course of internal spontaneous processes. This is reflected in the equations of the balance of these quantities, which are similar in meaning to the equations of the balance of entropy. This approach means refusal to calculate the external energy exchange of the system by changing the parameters Θ_i, R_i, and the transition to direct measurement of energy carrier fluxes through the boundaries of the system $J_i = \Theta_i \upsilon_i$, where $\upsilon_i = dR_i/dt$.

The second sum of identity (3), on the contrary, owes its origin to the spatial heterogeneity of the systems under study. Its terms also characterize the elementary work of the same kind as in mechanics, which is determined by the product of the resulting force of the *i*-th kind F_i by the displacement dR_i caused by it of the object of its application (in this case, the value Θ_i). This work is different from those included in the first sum (3). Since the forces in (3) are under the conditions of constant parameters Θ_i, then $F_i \equiv -\partial U/\partial R_i = \Theta_i X_i$, where $X_i = -\partial U/\partial Z_i$. The work $dW_i = F_i \cdot dR_i = X_i \cdot dZ_i$ performed by the forces F_i or X_i consists in the redistribution of the energy carrier Θ_i over the volume of the system. Thus, energy dynamics introduces into consideration a new class of transfer processes that have a vector (directed, ordered) character.

In the particular case of homogeneous systems ($\Delta R_i = 0$), expression (3) turns into the combined equation of the 1st and 2nd principles of classical thermodynamics of open systems in the form of the Gibbs relation [21]:

$$dU = \Sigma_i \Psi_i d\Theta_i, \tag{4}$$

where $i = 1,2,\ldots, n$ is the number of independent energy carriers of the system.

At the same time, a unique feature of energy dynamics consists in obtaining many non-trivial consequences even before its application to specific systems. The latter, as is known, requires the use of uniqueness conditions, in that knowledge of the thermophysical properties of the object, its equations of state and transfer, boundary conditions, etc. Therefore, the consequences obtained directly from identity (4), before using the uniqueness conditions, acquire the status immutable truths.

III. Finding Driving Forces and Generalized Speeds of Biological Processes in Energodynamics

In contrast to the existing linear TIP, energy dynamics introduces thermodynamic forces X_i and flows of energy carrier J_i on a more general basis of the law of conservation of energy, and not the principle of increasing entropy. In L. Onsager's "quasithermodynamics" [27] dealing with relaxation processes, their scalar analogs X_i^* and J_i^* are found from the expression for the rate of entropy increase in an adiabatically isolated system dS/dt:

$$dS/dt = \Sigma_i X_i^* J_i^*, \tag{5}$$

where $X_i \equiv \partial S/\partial \alpha_i$ is "thermodynamic force" as a measure of the deviation of some *i*-th parameter of the system α_i from its equilibrium value α_{io}; $J_i \equiv d\alpha_i/dt$ is the generalized rate of the *i*-th relaxation process.

However, since the parameters α_i are obviously absent in equilibrium thermodynamics, Onsager's theory was a kind of formalism that has nothing to do with reality. The situation changed when I. Prigogine proposed to move on to the study of the so-called "stationary irreversible processes", in which the parameters X_i and J_i acquire a vector nature and are maintained unchanged by means of "external compulsion", that is, performing work on the system dW_i" against equilibrium". In this case, the parameters X_i and J_i can be found from disciplines operating with the concept of work, by separating from dS/dt that part of it d_iS/dtthat is responsible for the "production of entropy" and is numerically equal to the work done on the system dW_i/dt. However, this required the compilation of cumbersome equations for the balance of energy, mass, charge, momentum, entropy, etc. in order to isolate from them the irreversible part of the process associated with the production of entropy d_iS/dt. This most time-consuming part of the TIP application required from the user not only an outstanding knowledge of the relevant fundamental disciplines, but also the application of a number of hypotheses, since these disciplines were deliberately limited to the consideration of conservative (nondissipative) systems and did not contain dissipative terms. This was the main reason why teaching consumer goods in higher education turned out to be unrealistic.

The situation is completely different in energy dynamics, where the sought forces X_i and fluxes J_i are already contained in its basic identity (3). At the same time, the arbitrariness inherent in TIP in the choice of driving forces and generalized speeds of transfer processes is eliminated, and the concept of force and generalized speed of the process becomes the same for all disciplines. So, if the first sum (3) includes the term TdS, which characterizes reversible heat transfer in the combined equation of the 1st and 2nd principles of classical thermodynamics, then the term $X_s \cdot J_s$, will appear in the 2nd sum (3), where $X_s = -\text{grad}\ T$ is the specific "thermomotive" force, $J_s = S\upsilon_s$ is the entropy flux. Similarly, if the first sum (3) includes the term pdV, which characterizes the reversible work of expansion, then in the second sum (3) there will appear an additional term $X_\text{v} \cdot J_\text{v}$, which characterizes the process of contraction of some and expansion of other parts systems, for example, the ventricle and atrium (X_v = –grad p,J_v is volumetric flow). In the same way, if the first sum (3) includes the term $M_k dN_k$, which characterizes the reversible transfer of the k-th substance through the boundaries of the system, then in the second sum (3) there will appear a term $X_k \cdot J_k$, which characterizes the work separation of this substance in the cell membrane or in the dialyzer (X_k = -grad M_k, $J_k = N_k v_k$ is the flow of the kth substance). Similarly, driving forces can be found in so-called "complex" systems that perform other types of work besides expansion work. So, if the term $\varphi d\Theta_e$ is included in the 1st sum (3), which characterizes the reversible work of introducing an electric charge Θ_e into the region with an average electric potential φ, then in the second sum (3) the term $X_e \cdot J_e$, creating the elementary work of separating charges in the cell membrane or in a galvanic cell ($X_e \equiv E$ = –grad$\varphi$is electric field strength, J_e - electric current).

It is easy to see that the terms of the second sum (3) can have different signs depending on whether the system is doing work or work is being done on the system. This is the fundamental difference between the proposed method and TIP, in which the $X_i \cdot J_i$terms are always positive (as well as "entropy production"). Meanwhile, in biosystems that consume free energy from the environment, $X_i \cdot J_i < 0$, which contradicts (5) and leads to absurdities such as “negentropy production”. In addition to eliminating it, this approach allows energy dynamics to study real processes, not excluding from consideration any (reversible or irreversible) component.

A significant advantage of this approach is also that it eliminates the need to draw up cumbersome equations for the balance of energy, mass, charge, momentum, entropy, etc. It is also important that energy dynamics acquires the ability to reflect on a quantitative and qualitative level the emergence of new (emergent) properties in the system. Indeed, the parameters Z_i are absent in equilibrium systems ($\Delta R_i = 0$) and their elements, and arise only when they deviate from a uniform state. Thus, energy dynamics is distinguished by taking into account not only the local nonequilibrium of the studied systems ($\nabla \psi_i \neq 0$), but also the ability to reflect the evolution of biosystems, which consists in the appearance of new properties in them. In the future, this also makes it possible to substantiate the dialectical unity of the processes of evolution and involution [30]. In addition, the unity of the dimensions of forces of various natures F_i opens up the possibility of finding their resultant $F = \Sigma_i F_i$, which subsequently makes it possible to significantly simplify the transport equations.

IV. Correction of the Equations of "Passive Transport" in Biosystems

In L. Onsager's “quasi-thermodynamics” [27], it is postulated that each of the fluxes J_i linearly depends on all thermodynamic acting in the system forcesX_j(j=1,2,…,n). The corresponding equations are called the "phenomenological laws of Onsager":

$$J_i = \Sigma_j L_{ij} X_j. \qquad (6)$$

Here L_{ij} is constant (independent of X_j) kinetic coefficients, called phenomenological and obeying the so-called "reciprocity relations" Onsager $L_{ij} = L_{ji}$. These ratios reflect, in his opinion, the interconnection of the J_i flows, which is the reason for the appearance of the aforementioned “side” effects of their “overlap”.

According to (6), the terms $J_{ij} = L_{ij} X_j$ of the flow $J_i = \Sigma_j J_{ij}$ have the same sign This is natural for the case of purely dissipative processes, when the total rate of approach of the system to equilibrium is the sum of the rates of individual relaxation processes. Meanwhile, a class of so-called "conjugate" processes is known, when some of them proceed in the direction of equilibrium, while others, on the contrary, remove it from equilibrium. Such, for example, are the Belousov-Zhabotinsky cyclic reactions called "chemical clocks" [31], "active transport" in biosystems (transfer of substances to the region of increased reaction affinity) [32], "ascending diffusion" in metals and alloys [33], the processes of concentration of matter in the Universe [30], etc. This means that at least some of the forces and flows have the opposite sign, that is, when some i-th relaxation process occurs, the system moves away from equilibrium on other, j-th degrees of freedom. In other words, along with dissipative phenomena in such systems, processes of opposite direction are observed. These include, in particular, the transfer of a substance to an area with its increased concentration (the so-called "ascending diffusion"), the phenomenon of "self-organization" of biosystems, processes of structure formation in solutions and melts. the state of equilibrium is possible only by performing useful work on it, we have to admit that in biosystems, along with external work, internal work is performed against some of the forces X_j, which is not associated with the production of entropy. Equations (6) do not take into account this specificity of systems performing useful work. This makes TIP inapplicable to biosystems.

The interpretation of the effects of superposition of heterogeneous processes in consumer goods is also erroneous. Indeed, if the flows J_i in the consumer goods are found as time t derivatives of the independent parameters α_i, then they are also independent of each other and therefore cannot interact (overlap). This is especially obvious for stationary states, when part of the "superimposed" flows simply disappears, and the effects of "superimposition" nevertheless take on a maximum value. This means that the explanation of various (thermomechanical, thermoelectric, thermochemical, electromagnetic, etc. effects) in consumer goods as a consequence of the interaction of dissimilar flows, and not the summation of forces, does not correspond to the essence of the matter.

The transfer equations from the standpoint of energy dynamics appear in a completely different light. Like classical thermodynamics, it involves any equations (state or transfer) from the outside as a kind of uniqueness condition describing the properties of specific systems. At the same time, the mathematical apparatus of thermodynamics and energy dynamics, based on the properties of the total differential of a number of state functions, does not depend on these equations. As is known from mechanics, for each independent transfer process there is a unique (resultant) force F_i, which generates this process and disappears when it stops [25]. The components of this force F_{ij} differ in their physical nature, however, unlike $\mathbf{X}_i$, they have the same dimension [N]. If such (resulting) force is found, $L_{ji}\mathbf{X}_i = 0$and laws (6) take the so-called "diagonal" form, similar to the equations of heat conduction, electrical conductivity, diffusion, etc. and does not contain cross terms with $i \neq j$ [34]:

$$J_i = L_{ii}F_i = L_{ii}\Sigma_j F_{ij}. \qquad (7)$$

In this case, Onsager's reciprocity relations are fulfilled trivially ($L_{ij} = L_{ji} = 0$) and become redundant, and with them the requirement of linearity of laws (6), which is necessary for their fulfillment. This means that the phenomenological coefficients L_{ii} in (7) can be arbitrary functions of the variables Θ_i and the forces F_{ij}, while laws (6) in the general case can be nonlinear. In particular, as shown in [24], the laws of passive transport of k-th substances take the form:

$$J_\kappa = L_k\mathbf{X}_\kappa = -L_k\nabla\mu_k, \qquad (8)$$

where L_k are the coefficients of osmotic diffusion of the kth substance, depending on the fields of temperature, pressure and concentration of all independent components of the system; $\nabla\mu_k$is drop in the chemical potential on the membrane. Meanwhile, in the diffusion laws proposed by Osager himself, the sum $\nabla\mu_k$ appears, as in (5) [27]. In the diagonal form of laws (7.8), their nonlinearity, associated with the variability of the coefficients L_k, no longer interferes with the finding of superposition effects. Let us show this by the example of a biological membrane permeable to the k-th substance. Expanding the expression for the total differential of the chemical potential μ as a function of temperature, pressure and concentrations of all j-th independent components of the system (j = 2,3, ..., K), we have:

$$d\mu_k = (\partial\mu_k/\partial T)\, dT + (\partial\mu_k/\partial p)\, dp + \Sigma_j(\partial\mu_k/\partial c_j)\, dc_j. \qquad (9)$$

This means that the transfer equation (6) for discontinuous media in their expanded form has the form:

$$J_\kappa = -L_k[(\partial\mu_k/\partial T)\,\Delta T + (\partial\mu_k/\partial p)\,\Delta p + \Sigma_j(\partial\mu_k/\partial c_j)\,\Delta c_j], \qquad (10)$$

where ΔT, Δp, Δc_j are temperature, pressure and concentration drops of j-th substances on the membrane. The terms of this expression are the components of the resulting force $\mathbf{X}_\kappa = -\Delta\mu_k$, the first of which is responsible for the phenomenon of thermal diffusion (transfer of matter due to temperature difference), the second - for the phenomenon of barodiffusion (transfer of matter due to pressure difference) , and the third - for the phenomenon of ordinary (concentration) diffusion. The mutual compensation of these components of the resulting force ($\mathbf{X}_\kappa = 0$) is the reason for the onset of a stationary state, which would be more correctly called the state of "partial equilibrium". In this case, the very stationary effects such as $\Delta T/\Delta p, \Delta T/\Delta c_j$и$\Delta p/\Delta c_j$ are obtained in energy dynamics as a result of the "superposition" of dissimilar forces, not flows.

In particular, from (10) at $J_k = 0$, regardless of the value of L_k, the well-known expression for the stationary effect of the appearance of the so-called osmotic pressure Δp in a binary isothermal system (the first component is a solvent) follows directly:

$$(\Delta p/\Delta c_2)_{st} = -(\partial\mu_1/\partial c_2)/(\partial\mu_1/\partial p), \qquad (11)$$

Here Δc_2 is the stationary difference in the concentration of the solute on both sides of the biological membrane.

This made it possible to propose a method for studying superposition effects in nonlinear systems [23], which opens up the possibility of studying the kinetics of processes in biosystems that are far from equilibrium.

V. Establishing the Relationship of Chemical Reactions with Metabolic Processes

When applying the TIP to phenomena of different tensor rank and type, it turned out that, in accordance with the Curie principle (which establishes the conditions for the preservation of bonds during coordinate transformations), the generalized rate of a process in equations of the type (1) can depend only on thermodynamic forces of the same (or even) of tensor rank [1,2]. This meant that the chemical reactions described in TIP by the terms $\Sigma_r A_r d\xi_r$ (where A_r is the standard chemical affinity of the rth chemical reaction, ξ_r is the degree of its completeness), i.e., as scalar processes, cannot interact with the processes of metabolism (exchange substances) having a vector nature. There was an obvious contradiction between TIP and biology, for which it is precisely this interaction that plays a decisive role in the life processes of biosystems. To resolve this contradiction, I. Prigogine put forward the theory of "stationary conjugation", in which the fact of the presence of active transport of substances through biological membranes due to the occurrence of chemical reactions on them was explained by the specificity of stationary states with their inherent ratios between the costs of individual reagents. However, it remained unclear why the aforementioned relationship of chemical reactions with metabolic processes persisted in non-stationary regimes. The answer to this question is given by the basic identity of energy dynamics in the form (4). If the term $\Sigma_r A_r d\xi_r$ appears in its first sum, describing the *r*-th scalar chemical reactions in homogeneous media, then in the second sum (4) additional terms of the vector nature $\Sigma_r X_r \cdot J_r$, reactors, Van't Hoff boxes, cell reactors, etc.), where $X_r = -\,\mathrm{grad}(A_r\xi_r)$;$A_r\xi_r$ is the local value of the chemical affinity of the *r*-th chemical reaction in a given cross-section of the flow reactor; J_r is the flow of reagents participating in it. Indeed, for steady-state reactions, the term $\Sigma_r A_r d\xi_r$ can be represented as $\Sigma_r[\partial(A_r\xi_r)/\partial R_m]\ dR_m = \Sigma_r F_r \cdot dR_m$, where $F_r = grad(A_r\xi_r)$is the local value of the driving force of the *r*-th flow chemical reaction; R_m is the coordinate of the "reaction front" in the flow reactor. In this case, the laws of active transport of substances in membranes take the form:

$$J_m = -L_m \Sigma_r \nabla(A_r\xi_r), \qquad (12)$$

where $J_m = \Sigma_k N_k dR_m/dt$ is the flow of chemically reacting substances through the biological membrane. Thus, under conditions of spatial separation of reagents (as in a Van't Hoff box), chemical reactions acquire a directional (vector) character, which determines their interaction with metabolic processes in full accordance with the Curie principle. In the absence of the transfer of reagents in the field of intermolecular forces, chemical reactions inevitably acquire a dissipative character, which is taken into account in TIP by assigning the term $\Sigma_r A_r d\xi_r$ entirely to heat sources. This removes one of the main contradictions between consumer goods and bioenergetics [24].

VI. CRITERIA FOR THE EVOLUTION AND INVOLUTION OF BIOLOGICAL SYSTEMS

In classical and nonequilibrium thermodynamics, there are no parameters or state functions that could be quite general and strict criteria for the development (ontogenesis) and evolution (phylogenesis) of biosystems. Entropy S is not applicable for this purpose, since in biosystems exchanging energy and matter with the environment, it can change due to heat transfer or mass transfer and, on the contrary, remain unchanged if the system moves away from equilibrium or approaches it due to the performance of useful work.

As for the well-known thermodynamic potentials such as the Gibbs free energy G or Helmholtz F, they are defined, strictly speaking, only for closed homogeneous systems and are not applicable in the boundary conditions specified by the flows of matter [27]. It cannot serve as a measure of the ordering of a biosystem and its exergy (technical performance) of extended systems [35], since it depends on the energy supplied from the outside in the process of performing work, as well as on environmental parameters, and is not a function of the state of such systems.

The so-called "production" of entropy d_iS/dt(the rate of its increase due to irreversibility) also does not meet these requirements, since this indicator has a minimum only for stationary states of linear systems, and then only near equilibrium [36]. The way out of the situation is again prompted by energodynamics.

Let us pay attention to the second term (3), which determines the algebraic sum of all types of work (external and internal, useful and dissipative, mechanical and non-mechanical) that can be performed by the open system under study with an arbitrary number of nonequilibrium degrees of freedom $i = 1.2, \dots n$. This sum characterizes the transformed (non-equilibrium) part of the internal energy of a spatially heterogeneous system, which we called "*inergy*" I(as opposed to the equilibrium, non-workable part of the energy$U - I$, which we named after Z. Rant (1955) "*anergy*"). Inergy$I$ as a non-equilibrium (ordered) part of the internal energy U is a function exclusively of the parameters of the spatial inhomogeneity Z_i or ΔR_i. According to (3), a homogeneous system ($R_i = 0$) cannot perform either external or internal work, since $dW = \Sigma_i F_i \cdot dR_i = 0$. This means that the measure of the efficiency of the system is precisely the energy as an ordered part of the energy of the system. This allows us to use its change as a very general criterion for the involution of the system, i.e., its degradation as it approaches the state of equilibrium, where $I = 0$:

$$dI = -\Sigma_i F_i \cdot dR_i \leq 0. \qquad (13)$$

Here the sign $<$refers to the relaxation processes of the system; an equal sign - to a state of balance.

On the contrary, the increase in the system's inergy$I$due to its removal from equilibrium under the influence of external work can serve as a criterion for its evolution:

$$dI = -\Sigma_i F_i \cdot dR_i > 0. \qquad (14)$$

According to (3), the parameters ΔR_i can be found directly from the known density fields of the corresponding energy carrier Θ_i, and other parameters of nonequilibrium $Z_i=\Theta_i\Delta R_i$ and $X_i= - \partial U/\partial Z_i$ are determined from them. All three of these parameters can serve as non-entropic criteria for the evolution of the system [36]. The advantage of these criteria over entropy is that they are able to reflect the evolution of the system for each of its inherent degrees of freedom (mechanical, thermal, baric, chemical, electrical, etc.), and not only its approach to equilibrium, but also distance from it:

$$dX_i,\ dZ_i,\ dR_i < 0 \text{ (involution)}, \qquad (15)$$

$$dX_i,\ dZ_i,\ dR_i > 0 \text{ (evolution)}. \qquad (16)$$

This makes it possible to detect the opposite direction of processes not only in different degrees of freedom of the system, but also in its different parts (regions, phases and components) of the system. Since in isolated systems all processes are spontaneous, such an analysis makes meaningful the concept of self-organization of individual degrees of freedom of the system, which does not contradict thermodynamics due to the absence of such for an isolated system as a whole.

VII. Description of Energy Conversion Processes in Biosystems

The specificity of energy conversion processes in biosystems is the appearance of additional interrelationships between the rates of dissimilar processes and the flows J_i and J_j of the converted and converted forms of energy. The presence of such a connection is easy to detect on the basis of the law of conservation of energy in the form (3), from which it follows that with a complete transformation of the *i*-th form of energy into the *j*-th

$$X_i{\cdot}J_i = -X_j{\cdot}J_j. \qquad (17)$$

This relationship is reflected by the differential relationships of reciprocity, which are invariably antisymmetric for energy conversion processes [15]:

$$\partial J_i/\partial X_j=L_{ij}= -\partial J_j/\partial X_i= -L_{ji}. \qquad (18)$$

This (antisymmetric) nature of reciprocity relations is due to the different sign of the work performed by the forces X_i and X_j and does not depend, as shown in [12], on whether these forces belong to even or odd functions of time. In the particular case of linear systems, relations (12) transform into the Casimir antisymmetry conditions $L_{ij} = - L_{ji}$[2,3]. This means that in the linear approximation, the phenomenological laws of energy transformation take the form:

$$J_i =L_{ij}X_i - L_{ij}X_j. \qquad (19)$$

$$J_j =L_{ji}X_i - L_{jj}X_j. \qquad (20)$$

Unlike (6), these laws reflect a decrease in the flow of the primary energy carrier J_i as the overcome force X_j increases and approaches the "idle" mode. Therefore, it is these equations, and not the relations (6) postulated by L. Onsager, that should be called phenomenological (i.e., based on experience) laws.

Let us consider, as an example, an element of a muscle - a fibril, which has the ability to contract when a chemical reaction starts, that is, it converts chemical energy into mechanical energy. In accordance with this, we will take the flow of substances J_r participating in a given chemical reaction as the flow of the primary energy carrier J_i, and the rate of muscle contraction as the second flow J_j. Each of these flows, in accordance with (19) and (20), depends on both forces, the first of which X_i in this case is the negative gradient of the chemical affinity of the reaction – grad($A_r\xi_r$), and the other is the contraction force of the fibril X_j. Note that in the case when the chemical reaction goes to the end ($\xi_r = 1$), the force X_i is numerically equal to the standard affinity of the chemical reaction A_r. Since chemical reactions are usually described as scalar, in the future we will operate with the modules of forces and flows.

It is more convenient to represent laws (19) and (20) in a dimensionless form that does not contain phenomenological coefficients. For example, consider the regime of the so-called "isometric muscle contraction" when $J_j = 0$, as well as "unloaded muscle contraction" when $X_j = 0$. Expressing X_{jo} and J_{jk} in terms of phenomenological coefficients (assuming their constancy), we find under conditions of constancy of forces X_i:

$$X_j/X_{jo}+ J_j/J_{jk}= 1. \qquad (21)$$

To confirm the applicability of these equations to biological systems, we will use the experimentally found kinetic Hill equations, which quite accurately describe the characteristics of muscles taken from various animal species [5]. The load characteristics of the muscle propellers built on their basis are shown in Figure 2.

Curves 1, 2, 3, 4 in this figure correspond to different degrees of nonlinearity of Hill's kinetic equations. This nonlinearity is usually explained by the relationship between the rates of both processes (flows $J_i$and J_j) [4]. In linear systems, the dependence of X_j/X_{jo}on J_j/J_{jk} in linear systems is expressed by a straight line intersecting the ordinate axes at $J_j/J_{jk}= 1$ and $X_j/X_j= 1$ (curve 1). It is easy to see that it is precisely this character that follows from the kinetic laws (15). Consequently, the work of the muscle and its element, the fibril, obeys the universal laws of energy dynamics, and the modes of isometric muscle contraction and its unloaded contraction are similar to the modes of shortcircuiting and no-load and of a motor or a welding transformer.

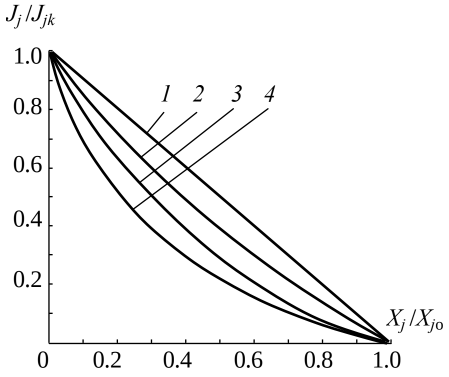

Figure 2: Load characteristic of the muscular propeller

Thus, the unity of the laws of energy transformation in technical and biological systems is revealed, which makes it possible to transfer the research results of some of them to others. At the same time, another reason for the inapplicability of consumer goods to biological energy converters is revealed. It consists in the fact that when forces and flows are found on the basis of expression (1) TIP, a limitation of the magnitude of their relative efficiency (less than 30%) arises, which is not characteristic of real energy converters (less than 30%) [37]. This limitation, however, is absent in the case of antisymmetric reciprocity relations. This confirms once again the inadmissibility of the formal transfer of the known provisions of the theory of irreversible processes to systems that perform useful work.

The independence of Eq. (21) from the structure and size of fibillae allows the theory of the similarity of muscle movers, similar to that for power plants [37]. This theory makes it possible to form a number of dimensionless criteria for the similarity of such systems. One of them, the "design criterion" $\Phi = R_{ij}R_{ji}/R_{ii}R_{jj}$, is analogous to the ratio of reactive and active resistances, known in radio engineering as the *Q*-factor of the circuit, and coincides (up to a temperature factor) with the "*Q*-factor" Φ, introduced A. Ioffe as a generalizing characteristic of thermoelectric generators (TEG). Its value fluctuates from zero to infinity ($0<\Phi<1$), increasing with a decrease in "active" resistances (from the side of dissipation forces) R_{ii} and R_{jj} and an increase in "reactive" resistances R_{ji} (from the side of the useful load). Like thermal resistances in the theory of heat transfer, these resistances depend on the properties of muscle tissues and their section, composition, etc.

Another dimensionless criterion $B = J_j/J_{jk} = 1 - X_j/X_{j0}$, called the "relative load", is composed of the boundary conditions specified by the value of the forces X_j, X_{j0} or flows J_j, J_{jk}. It changes from zero in the "idle" mode ("unloaded muscle contraction) to one in the" short circuit "mode (X_j=0). Using these criteria, expression (23) can be given the form of a criterion equation for the energy conversion process:

$$\eta_N=(1–B)/(1+1/B\Phi). \qquad (22)$$

Here $\eta_N = N_j/N_i$ is the efficiency of the process, expressed by the ratio of the output N_j and the input N_i power, and therefore we called it power. It generalizes the concept of relative efficiency η_{oi} in classical thermodynamics. This efficiency complements the well-known concept of taking into account the kinetics of the energy conversion process and therefore most fully reflects the perfection of the converter, that is, the degree to which it realizes the possibilities that nature provides.

The criterion equation (22) allows constructing a universal load characteristic expressing the dependence of this efficiency η_N on the power N_j and load B, as well as the perfection of the energy converter (Figure 3) [37]. The solid lines on it show the dependence of the efficiency η_N on the load criterion B at various values of the quality factor Φ, and the dash-dotted line shows the dependence on the load of its output power N_j. As follows from the figure, the efficiency of any power plant vanishes twice: at idle (B = 0) and in the “short circuit” mode (B = 1). In this case, the loads corresponding to the maximum efficiency and maximum power diverge the more noticeably, the more perfect the muscular mover. In the absence of any energy losses (from friction, heat release, all kinds of "leaks" of reagents, losses at idle run of the installation, etc., i.e., at $\Phi = \infty$), the power efficiency of the installation increases linearly with decreasing load, and at $B \rightarrow 0$ reaches, as expected, unity. This case corresponds to the ideal Carnot machine, which has the highest thermodynamic efficiency. However, the power of the converter in this mode approaches zero. This indicates the existence of an optimum in terms of efficiency. A mode similar to the nominal mode of the power plant. The versatile features make it easy to find such a compromise. Thus, one more step is taken towards the approximation of the results of the theoretical analysis of the converter to reality.

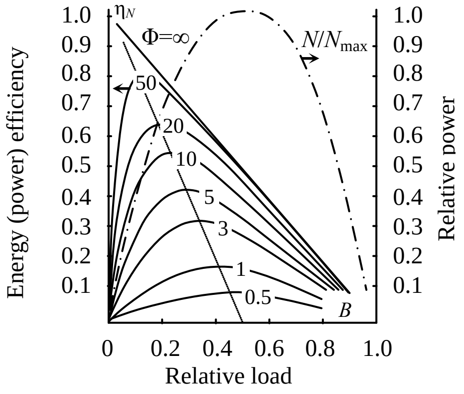

Figure 3: Universal load characteristics of linear energy converters systems

VIII. The Principle of Survival" as the Basic Law of the Evolution of Biosystems

Let us apply the basic identity of energy dynamics (3) to the processes of evolution of biosystems. Introducing the missing nonequilibrium parameters X_i and ΔR_i into it allows us to obtain a number of nontrivial consequences for them [38]. One of them is the conclusion that after the isolation of the nonequilibrium system ($dU/dt = 0$) the processes of energy interconversion, obeying the condition

$$\Sigma_i X_i \cdot J_i = 0. \tag{23}$$

Let us now take into account that a change in any parameter Z_i can be caused not only by relaxation of the i-th degree of freedom, but also by the performance of external W_i^e and internal W_i^u work by forces F_i and X_i. This circumstance can be expressed by the balance equations of the quantity Z_i, similar to the equations of entropy balance proposed by I. Prigogine:

$$dZ_i = d_eZ_i + d_uZ_i + d_rZ_i, \tag{24}$$

where $d_eZ_i = \text{đ}W_i^e/X_i$; $d_uZ_i = \text{đ}W_i^u/X_i$; $d_rZ_i = \text{đ}W_i^r/X_i < 0$ are the components of the total change in the parameter Z_i, caused by the performance of external W_i^e, internal W_i^u and dissipative W_i^r work, respectively.

Accordingly, the flow $J_i = dZ_i/dt$ as the generalized speed of any i-th process includes external $J_i^{\mathbf{e}}$, reversible internal J_i^u and dissipative internal J_i^r components:

$$J_i = d_eZ_i/dt + d_uZ_i/dt + d_rZ_i/dt = J_i^{\mathbf{e}} + J_i^u + J_i^r. \tag{25}$$

In this case, condition (24) in isolated systems ($J_i^{\mathbf{e}} = 0$) takes the form:

$$\Sigma_i X_i \cdot (J_i^u + J_i^r) = 0. \tag{26}$$

According to this expression, as long as relaxation processes are going on in the system ($J_i^r \neq 0$), oppositely directed (anti-dissipative) processes of doing internal work “against equilibrium” will also take place in it. In energodynamics, this position is called the “principle of counter-directionality” of non-equilibrium processes, which can be regarded as a mathematical expressiln this case, this principle means that the approach to equilibrium of some degrees of freedom of the system ($X_i \cdot J_i > 0$) is accompanied by the distance from it of other, j-th degrees of freedom ($X_i \cdot J_i < 0$). Hence follows the unity of the processes of evolution (complication) and involution (degradation) of non-equilibrium systems. Unlike classical thermodynamics, which cannot say anything about the rate of approach of a biosystem to equilibrium, energy dynamics allows us to raise the question of the rate of approach of the system to a state of equilibrium and the effect of the complexity of a biosystem and its remoteness from a state of equilibrium on the duration of its life. According to (3), under comparable conditions, the rate of relaxation of the system prescribed by the 2nd law of thermodynamics depends on the rate of reversible processes Jiu, with the necessity arising in it due to the principle of oppositely directed nonequilibrium processes. In this case, it is of undoubted interest to compare the speed of approaching equilibrium of two arbitrary biosystems of different complexity (with a different number of degrees of freedom).

If, in an arbitrary system, we somehow "freeze" chemical or any other processes associated with the performance of reversible internal work (that is, to direct J_iu to zero), then the speed of its approach to equilibrium dU^r/dtwill become equal to

$$dI/dt = -\,\Sigma_i X_i \cdot J_i^r. \tag{27}$$

Comparing (23) and (26), we find that their ratio is determined by the expression:

$$dU/dI = 1 + \Sigma_i X_i \cdot J_i^u / \Sigma_i X_i \cdot J_i^r. \tag{28}$$

It is easy to see that this ratio can be either greater or less than one, depending on the sign of the sum $\Sigma_i X_i \cdot J_i^u$, since $\Sigma_i X_i \cdot J_i^r$ is always positive. If $\Sigma_i X_i \cdot J_i^u < 0$, that is, there is work “against equilibrium” (and forces X_i) in the system, then the speed of approach of such a system to equilibrium decreases in comparison with a system where such processes are absent:

$$dU/dI = 1 - \Sigma_i X_i \cdot J_i^u / \Sigma_i X_i \cdot J_i^r, \tag{29}$$

and can become equal to zero when work "against equilibrium" becomes equal to work of a dissipative nature. This case corresponds to the onset of a stationary state. Among the macroprocesses in which such counter-directional changes of state take place is the so-called "active transport" of substances, which leads to the accumulation of reagents with a relatively high Gibbs energy in the corresponding organs. The same are the already mentioned processes of "ascending diffusion" in alloys, as well as the so-called "conjugate chemical reactions". Some of them, like the Belousov-Zhabotinsky cyclical reactions ("chemical clocks") or the process of the circulation of matter in the Universe, can continue indefinitely. All processes of this kind require a certain organization of the system and therefore arise only at a certain stage of their evolution. The life span of biosystems, as well as their reproductive period, depends on their intensity, which affects the evolution of the entire subsequent population of this type of bioorganisms.

Here lies the key to understanding the general direction of the evolution of a biological system, understood as a transition from simple to complex. This direction of evolution is not something imposed by the "higher mind" or Darwinian "struggle for existence" - it is a consequence of purely physical reasons reflected in the energodynamic principle of "opposite direction" of nonequilibrium processes. Such are any processes leading to the ordering of the system, the acquisition of new properties by it (an increase in the number of degrees of freedom), the complication of the structure, etc.

At the same time, the "postponement" of the onset of equilibrium in biosystems, achieved due to the occurrence of reversible processes in them, is so close to the Darwinian idea of "struggle for existence" that it can also be called the "principle of survival" for clarity. This principle can be formulated briefly in the form of a statement: "Evolutionary processes occurring in biological systems are directed towards increasing the duration of their life." This provision is so general that it can be considered the basic law of biological evolution.

This law does not at all contradict classical thermodynamics and its second principle, which removes their "flagrant contradiction" noted by I. Prigogine. At the same time, he debunks the myth of “the emergence of order from chaos” [20], since it becomes clear that maintaining “order” requires the expenditure of work, the absence of which in isolated systems is inevitably accompanied by a decrease in their ordered energy. In other words, "order" in any part of the system (subsystem) arises not from ha-os, but due to a higher order in other parts of the system or in the surrounding force fields. For biological systems, these are radiation fields, flora and fauna, which have ordered forms of energy. This radically changes our worldview.

IX. Energodynamics and Darwinian Theory of Evolution

Let us now show that the well-known "triad" of Darwin's doctrine of evolution [] - adaptability, variability and heredity - are a consequence of the above formulated energy-dynamic law of evolution. Considering biological objects as non-equilibrium systems immersed in a nonequilibrium environment, energy dynamics deepens our understanding of equilibrium. It is one thing when both the system and the environment are homogeneous (that is, they lack both long-range and short-range force fields). Then their equilibrium corresponds to the termination of processes both in the environment and in the system. The condition for such external equilibrium is the equality of the corresponding potential (temperature, pressure, chemical, electrical, etc. potentials) in all parts of the system and the environment. The resulting forces X_i in this case are equal to zero, which corresponds to inaction. It is with this kind of external equilibrium that classical thermodynamics deals. However, the concept of force was alien to classical thermodynamics. Therefore, she distorted the meaning of the concept of equilibrium as an equal action of forces, replacing it with inaction (the absence of any processes).

A different kind of state occurs when both the system and the environment are heterogeneous and the thermodynamic forces X_i in them are nonzero. Then the external equilibrium means their equal action, which does not exclude the occurrence of internal processes in the system and in the environment. Thus, external balance does not at all mean the presence of complete (external and internal) balance. It is with this case that the thermodynamics of biological and ecological processes deals. Equilibrium establishment processes of this kind are adiabatic and therefore do not obey the entropic criteria of evolution and equilibrium. Meanwhile, it is these processes that are responsible for the evolution of biological systems in the direction of establishing a balance between them and the environment. This is Darwinian adaptability in its energy-dynamic understanding. In the course of such processes, the body acquires new properties (new degrees of freedom), which were absent in it in a state of internal balance. The lack of equilibrium with the environment is manifested in the presence of thermodynamic forces X_i, which generate a change in the state of both the system and its environment. This is the thermodynamic reason for the variability of organisms. The result of this process is the equality of the forces X_i in the system and the environment, and not their internal balance. Striving for such a balance by no means deprives the biosystem of the ability to perform useful external work and to internal interconversion of energy.

As follows from the principle of survival, partial equilibrium lengthens the time the system remains in a nonequilibrium state. Then, in the presence of inevitable mutations of the hereditary code, the degree of their probability increases. Thus, better "adapted" individuals acquire an advantage in the transmission of gene information. This is the energy-dynamic nature of heredity. It is characteristic that all three named basic provisions of the Darwinian doctrine of evolution turn out to be a consequence of a single criterion of "survival" - the minimum speed of the system approaching equilibrium.

In the "theory of neutrality" of evolution (L. Blumenfeld, 1977), energodynamics can explain the mechanism of elimination (preservation of random genetic changes), since the probability of this process from the standpoint of the "principle of survival" increases with the lengthening of the life of a better adapted (closer to external equilibrium) individual. In the theory of “jump-like evolution” (“punctualism”), energy dynamics can explain the jump-like increase in the rate of change of genes, since it recognizes the inevitability of “bifurcation” (branching of process trajectories) with distance from equilibrium. In the theory of "molecular evolution", energy dynamics is able to explain the change in the composition of living organisms in ontogenesis, since natural aging is accompanied by a decrease in their specific energy. Thus, energodynamics can serve as a touchstone for any of the evolutionary theories.

X. Conclusion

1. The reason for the "glaring contradiction" between equilibrium thermodynamics and the theory of biological evolution is the absence in its equations of time as a physical parameter and its inability to take into account the kinetics of real processes. This contradiction persists in the theory of irreversible processes, which excluded from consideration the reversible part of such processes.
2. Description of the state of nonequilibrium systems requires the introduction of intense X_i and extensive Z_i parameters of spatial in homogeneity, characterizing their deviation from equilibrium. These parameters have a number of advantages over entropy, reflecting the approach to equilibrium and the distance from it both for the system as a whole and for each of its inherent degrees of freedom separately.
3. The introduction of these parameters of spatial heterogeneity into thermodynamics reveals the occurrence in nonequilibrium systems of reversible processes of redistribution of energy carriers over the volume of the system and their opposite direction, reflecting the dialectical unity of opposites.
4. The use of these parameters X_i, Z_i and R_i as criteria for their evolution and involution reveals the inevitability of the simultaneous occurrence of these processes in different parts (regions, phases and components) of the nonequilibrium system and the interconversion of energy in them, accompanied not only by its relaxation, but and doing work "against equilibrium."
5. The processes of performing external and internal work in the muscle tissues of living organisms are subject to the same laws as the processes of energy conversion in various thermal and non-thermal machines. This makes it possible to create a theory of the similarity of muscular energy converters, which facilitates the selection of the optimal modes of their activity.
6. The course of oppositely directed processes in biological systems slows down their approach to equilibrium and makes it possible to formulate the “principle of their survival”, according to which their self-organization leads to an increase in the duration of their life. This provision is so general that it can be considered the basic law of biological evolution.
7. The energy-dynamic theory of evolution confirms the main provisions of the Darwinian theory of evolution (adaptability, variability and heredity), explaining them, however, by natural causes. Thus, any contradictions between thermodynamics and the theory of biological evolution are eliminated.

References Références Referencias

1. ***Де*** *Groot S., Masur P.* Non-equilibrium Themdynmics. Amsterdam, 1962.
2. *Haase R.* Themdynmik der Irreverdiblen Processe. Darmstadt, 2963.
3. *Katchalsky A., Curran PF.* Nonequilibrium Thermodynamics in Biophysics. Harvard Univ. Press, Cambridge, 1967.
4. *Keplen SR., Essig E.* Bioenergetics and linear thermodynamics of irreversible processes. Moscow: Mir, 1968 (in Russian).
5. *Prigogine I.* Introduction to Thermodynamics of Irreversible Processes. -Springfield, 1955.
6. *Rudenko AP.* The theory of self-development of open catalytic systems. M., Science, 1969(in Russian).
7. *Rubin AB.* Thermodynamics of biological processes. Moscow State University, 1984(in Russian).
8. *Gladyshev G.* Thermodynamics Theory of the Evolution of Living Beings. New York: Nova Science Publishers, Inc., 1997(in Russian).
9. *Demirel Y.* Nonequilibrium Thermodynamics. Transport and Rate Processes in Physical, Chemical and Biological Systems, 3rd ed. Amsterdam, 2014.
10. *Driesch H.* Die Biologie als selbständige Grundwissenschaft, Leipzig 1893.
11. Schrödinger E. Was is Leben? München, 1951.
12. *Bauer E. Theoretical biology.* M.- Spb.1935(in Russian).
13. *Blumenfeld LA.* Problems of Biological Physics. M., Nauka, 1977(in Russian).
14. *Shnol SE.* Physicochemical factors of biological evolution. M., Science, 1979(in Russian).
15. *Antonov VF.* Physics and biophysics. Ed. 3rd. M.Media, 2010(in Russian).
16. *Nicolis G., Prigogine I.* Self-organization in nonequilibrium systems: From dissipative structures to ordering through fluctuations. Moscow: Mir, 1979(in Russian).
17. *Haken G.* Synergetics. M., Mir, 1980(in Russian).
18. *Berger P., Pomo I., Vidal K.* Order in chaos. Moscow: Mir, 1991(in Russian).
19. *Danilov YA., Kadomtsev BB.* What is synergetics. // Nonlinear waves. Self-organization-nation. Moscow: Nauka, 1983(in Russian).
20. *Prigogine I.* Order and Haos, Man’s new dialog with Nature. London, 1984.

21. *Bazarov IP.* Thermodynamics. Edn4. M., Vysshaya shkola, 1991 (in Russian).
22. *Boltzmann L.* Selected Works. Moscow: Nauka, 1984
23. *Etkin V. A.* Synthesis and new applications of the energy transfer and energy conversion theories. (Summary of thesis for doct. techn. sciences. //Moscow: State Techn. Univ. Press, 1998. (in Russian).
24. *Etkin V.* Thermokinetics (Synthesis of Heat Engineering Theoretical Grounds).Haifa, 2010; *Etkin VA.* Thermokinetics (thermodynamics of nonequilibrium processes of transfer and transformation of energy). Togliatti, 1999(in Russian).
25. *Etkin V.* Energodynamics (Thermodynamic Fundamentals of Synergetics). N. Y., Lulu Inc., 2011;*Etkin VA.* Energodynamics (synthesis of theories of energy transfer and transformation). St. Petersburg, Science, 2008(in Russian).
26. *Tomson W.* Mathematical and physical papers. Cambridge, 1882. V.1.
27. *Onsager L.* Reciprocal relations in irreversible processes. //Phys. Rev., 237(14)1931.405-426;238 (12)1931.2265-2279.
28. *Poincare H.* Revue generale des Sciences pures et appliquees, 19(1908).386-402.
29. *GyarmatiI.* Non-Equilibrium Thermodynamics. Field Theory and Variation Principles. Springer–Verlag, 1970.
30. *Etkin V.* On the Dialectic Unity of Evolution and Involution. //Global Journal of Science Frontier Research: A Physics and Space Science. 20(10)2020.9-16.
31. *Zhabotinsky AM.* Concentration fluctuations. Moscow: Nauka, 1974(in Russian).
32. *Prigogine I., Defey R.* Chemical thermodynamics. Novosibirsk: Science, 1966(in Russian).
33. *Shumon PP.* Diffusion in solids. Moscow: Metallurgy, 1966(in Russian).
34. *Etkin V.A.* Uniqueness of driving forces of irreversible processes. // Russian Journal of Physical Chemistry, 63(6). 1989. 918-919 (translated from Zhurnal Fizicheskoi Khimii, 63(1989). 1660-1662).
35. *Etkin V.A.* On the uniqueness of the driving forces of irreversible processes.//Journal. physical Chemistry, 63 (1989) 1660-1662(translated from Zhurnal Fizicheskoi Khimii, 66(5)1992. 1205 -1212.
36. *Etkin VA.* New Criteria of Evolution and Involution of the Isolated Systems. //International Journal of Thermodynamics, 21(2), 2018,120-126.
37. *Etkin VA.* Similarity Theory of Energy Conversion Processes.// International Journal of Energy and Power Engineering, 8(1). 2019.4-11.
38. *Etkin V.* Verifiable Forecasts of Energodynamics.// Scientific Israel- Technological Advan-tages", 16(1,2)2014.130-137; *Etkin VA.* Non-trivial consequences of energy dynamics (Collection of articles). Lulu Inc., 2020.
39. *Etkin V.* Principle of non-equilibrium processes counter directivity. //Reports by independent authors, 37(2016), 86 – 92.
40. *Darwin Ch.* On the Origin of Spices by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life . London: John Murra, 1859.