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Relationship between Energy of Motion and D-Entropy in the Physics of Evolution

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Abstract

The purpose of the paper is to substantiate the possibility of constructing the physics of the evolution of matter based on the fundamental laws of physics. It is shown how this can be done within the framework of an extension of classical mechanics. Its expansion is based on the motion equation of a structured body. The fundamental difference between this equation and Newton's motion equation is that instead of a model of a body in the form of a material point, it uses a structured body in the form of a system of potentially interacting material points. To obtain this equation, the principle of symmetry dualism, new for classical mechanics, was used. According to this principle, the dynamics of a body are determined not only by the symmetries of space, as in the case of a structureless body, but also by its symmetries. Thanks to this derivation of the equation, it takes into account the fact that the work of external forces, in addition to changing the body's motion energy, also changes its internal energy. This change occurs due to the body's motion energy when it moves in a non-uniform field of forces. It is shown why the motion equation of a structured body is irreversible. Its irreversibility made it possible to introduce the concept of D-entropy into extended classical mechanics. It is defined as the value of the relative increase in the body's internal energy due to the motion energy. The relationship between the values of motion energy and D-entropy in the process of matter evolution is considered. It is shown how this connection is realized during the transition from one hierarchical level of matter to the next level. As a result, it was possible to prove that the evolution of the hierarchical structure of matter is characterized by the relationship between D-entropy and the motion energy of elements at each of its hierarchical levels.

Keywords

Dynamics, Symmetry, Mechanics, Energy, Entropy, Evolution

1. Introduction

The understanding of evolutionary processes and the development of their theory in modern physics have far from reached a level corresponding to the importance of the role of evolution in nature. As I. Prigogine said, today we have the physics of the "existing", but there is no "physics of the emerging" [1]. This is largely due to the fact that modern physics represents insufficiently connected and sometimes contradictory sections, while the nature of evolutionary processes is uniform and for its description requires the consistency of the laws of physics and its corresponding sections.

Motion is the way of existence of matter. Hence, classical physics can be represented in the form of two sections that are directly related to its dynamics.

The first section studies the dynamics of bodies based on the laws of classical mechanics, including Newton's laws. In this case, the main quantity characterizing the dynamics of bodies is the motion energy. Formalisms that make it possible to study the dynamics of systems are built based on the assumption of the potentiality of all collective forces and the condition of holonomy of connections. Moreover, the dynamics of bodies is studied without taking into account the processes of changing internal states. All this leads to the reversibility of classical mechanics. That is, the restrictions used in the construction of classical mechanics exclude the possibility of describing evolutionary processes that are inextricably linked with dissipation and irreversibility [2] [3].

The second section studies the internal states of bodies and their dependence on changes in external constraints. These studies are carried out within the framework of thermodynamics, statistical physics and kinetics for systems at rest, as a rule, equilibrium or close to equilibrium. At the same time, the role of motion and interaction of bodies in changing their internal states is not taken into account [4] [5]. The main quantities, characterizing the internal state of bodies, include internal energy and entropy. Moreover, internal processes are irreversible, which is consistent with the processes of evolution.

The evolution of bodies is characterized by the processes of formation, development and decay of systems, which are determined by the interrelationship of dynamics and changes in internal states. Therefore, a description of evolutionary processes is impossible without taking into account such a relationship. But for this, first of all, it is necessary to eliminate the contradictions between classical mechanics and thermodynamics. Thus, according to classical mechanics, all processes in nature are reversible, while thermodynamics states the opposite.

The probabilistic explanation of irreversibility proposed by Boltzmann and then developed by other authors is based on hypotheses about the existence of arbitrarily small external fluctuations that lead to the irreversibility of dynamics Hamiltonian systems due to exponential instability according to Lyapunov [6]. Taking into account the probabilistic explanation of the mechanism of irreversibility, work was also carried out on the development of statistical methods for analyzing the evolution of open nonequilibrium dynamic systems in time [7]. In

general, numerous attempts to find a solution to the problem of irreversibility within the framework of the formalisms of classical mechanics did not give the desired result [8] [9]. But even if we discard questions related to the absence of the concepts of probability in classical mechanics and the nature of external fluctuations, then still, when constructing a theory of the physics of evolution, one cannot rely on the probabilistic theory of fluctuations. Indeed, with a probabilistic description of evolution, the next question remains open: how this or another direction of development of evolution arises, why it goes "from simple to complex" [1] [6]. Moreover, the principle of causality is violated.

Relatively recently, the motion equation of a structured body (SB) was obtained. It uses a system of potentially interacting material points (MPs) as an SB. It, in contrast to Newton's motion equation for MP, is constructed taking into account the fact that the work of external forces changes not only the body's motion energy, but also its internal state [10] [11]. This made it possible to take into account the role of the dynamics of a body in changing its internal state and to link classical mechanics with thermodynamics together based on the fundamental laws of physics. Thus, the SB's motion equation opened up the possibility of constructing physics that describes the processes of emergence, development and destruction of natural systems within the framework of fundamental laws. The physics that studies these processes we proposed to call it "Physics of Evolution" [11]. The importance of its construction follows from the fact that it is hardly possible to find a branch of physics where questions of evolution do not arise. But so far, the development of "Physics of Evolution" is at an early stage. Its main content is an extension of classical mechanics. It consists of modifying the Lagrange, Hamilton, Liouville equations based on the SB motion equation. The construction of an evolutionary model of the infinite hierarchical structure of open nonequilibrium dynamic systems has also begun. The issues of describing bifurcation processes, phase transitions are considered, based on taking into account the dependence of macroprocesses on microprocesses at special points of phase trajectories, etc. [10] [11]. It is quite natural that many problems arise on the way to its further construction. One of these problems is associated with identifying key parameters characterizing the evolution of open nonequilibrium dynamic systems. The motion energy SB and D-entropy are proposed as such parameters. Accordingly, the purpose of this work is to substantiate this statement. To do this, let us explain how the SB motion equation is constructed, how the concept of D-entropy follows from it, and why the concepts of motion energy and D-entropy are key to describing the evolutionary processes of hierarchically structured matter.

2. The System's Motion Equation

In accordance with modern trends, the SB's motion equation was constructed based on the concept of symmetry [12]. From symmetry follows the requirement of invariance *of the total energy*, represented by the sum *of the motion energy*

and the SB's *internal energy* [4]. The derivation of the SB's motion equation was carried out based on of fundamental laws and principles applicable to both systems and their elements. These include the law of conservation of motion and Galileo's principle. In addition to them, the principle of dualism of symmetry (PDS) was used [13] [14]. According to this principle, *the motion of SB is determined by both spatial symmetry and body's internal symmetry.* It was also postulated that the laws for the system and the environment should be equally complete. These two provisions expanded the scope of application of classical mechanics, allowing it to describe dissipative processes, without which evolution is impossible. Let us explain the idea of deriving the SB's motion equation using the example of the well-known empirical motion equation that takes into account friction. It has the form [4]:

$$M\dot{V}_0 = -F_0 - \mu V_0, \tag{1}$$

Here M is the mass of the body; V_0 is the speed of the center of inertia of SB; F_0 is the force acting on the center of inertia; μ is the effective coefficient of friction.

In accordance with this equation, the body's motion energy is converted into its internal energy. The effectiveness of such a transformation is determined by the empirical coefficient μ. It turned out that this coefficient can be obtained analytically, that is, it is possible to find the body's motion equation with a functional dependence of friction on dynamic variables. This opens up the possibility of describing friction forces and dissipation within the framework of extended classical mechanics.

Let us consider the body's motion along an inclined rough surface under the influence of gravity. Let us define its model in the form of an SB, consisting of a sufficient number of potentially interacting MPs. According to Equation (1), part of the SB's motion energy in the gravitational field will go to change its kinetic energy. The other part will go to increase the internal energy SB due to the work of the friction force. That is, the work of external forces goes to increase the total velocity of all MPs, which determines the SB's motion energy, and to increase the chaotic components of the MP's velocities relative to the center of inertia, which determine the kinetic component of the internal energy. The total energy SB is equal to the sum of the motion and internal energy [4]. This also follows from equality [11]:

$$N\sum_{i=1}^{N} v_i^2 = NM_N V_N^2 + \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} v_{ij}^2 \tag{2}$$

The vector v_i determines the speed of the MP in the laboratory coordinate system; $i, j = 1,2,3,\cdots,N$ is MP number, where values i, j vary from 1 to N and $i \neq j$; $v_{ij} = v_i - v_j$; vector $V_N = \left(\sum_{i=1}^{N} v_i\right)\Big/N$ is the speed of the center of inertia SB; $M_N = Nm$; $m = 1$, $M_N = N$.

Equality (2) proves the independence of the variables that determine *the total energy* SB in the form of the sum of the motion energy and internal energy. The variables that determine the motion of SB are macrovariables, and the variables

that characterize the internal energy are microvariables.

The first term on the right-hand side of Equation (2) corresponds to the "*Order*" measure. It is maximum when the velocity vectors of all MPs are equal in magnitude and coincide in direction. The second term corresponds to the measure of "*Chaos*". It is maximum when the sum of all MP velocity vectors is zero.

It is known that the MP's motion equation can be obtained from the condition of invariance of the motion energy. In a similar way, but from the *total energy*, the SB's motion equation can be obtained. To do this, energy in accordance with the Equation (2), should be presented in micro- and macrovariables in the form of the sum of internal energy and the motion energy [4]. As will be seen from the further presentation, this way of obtaining the SB's motion equation allows us to take into account that when a body moves in a non-uniform field of external forces, the work of these forces goes both to change the motion energy of the body and to change its internal energy.

Full energy SB, represented by in micro- and macrovariables, has the form:

$$E_N = E_N^{tr} + E_N^{ins} = const \tag{3}$$

Here $E_N^{ins} = T_N^{ins} + U_N^{ins}$ is the internal energy SB, where $T_N^{ins} = \sum_{i=1}^{N} m\tilde{v}_i^2/2$ is the kinetic component of the internal energy; $E_N^{tr} = T_N^{tr} + U_N^{tr}$ is motion energy, T_N^{tr} is kinetic energy SB, depending on macrovariables, U_N^{tr} is potential energy SB in the field of external forces.

According to Equation (3), the work of external forces goes to change the motion energy and internal energy SB (dualism of work):

$$d\Im_N = dE_N^{tr} + dE_N^{int} \tag{3a}$$

The law of conservation of body energy for extended mechanics can be formulated as follows*: the sum of the motion energy and the internal energy of a body is invariant along its trajectory.* Moreover, each of these types of energy is not an invariant of motion. The SB's motion equation is obtained by differentiating Equation (3) with respect to time, followed by summing the values of energy changes for each MP. Under the condition of invariance of the total energy, it has the form:

$$M_N \dot{V}_N = -F_N^0 - \mu^d V_N, \tag{4}$$

where $F_N^0 = \sum_{i=1}^{N} F_i^0$; F_i^0 is external force acting on ith MP; $\mu^d = \dot{E}_N^{int} \Big/ \left(V_N^{max}\right)^2$; F_{ij} is interaction force i and j MP; $F_{ij}^0 = F_i^0 - F_j^0$;
$\dot{E}_N^{int} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} \left(m\dot{v}_{ij} + F_{ij}^0 + NF_{ij}\right)$; $V_N^{max} = -\dot{E}_N^{int} \Big/ F_N^0$.

Equation (4) takes into account the connection between the motion of each MP and the motion of SB. This connection is due to a decrease in the motion energy due to an increase in the chaotic components of the MP speeds relative to the center of inertia. First term in the right-hand side of the Equation (4) determines the external potential forces that change the speed of the center of inertia. Its appearance is due to the symmetry of space. The second term is due to taking into account the SB symmetry. It is bilinear, depends on micro- and macrova-

riables and is different from zero when the field of external forces is non-uniform. That is, provided: $F_{ij}^0 = F_i^0 - F_j^0 \neq 0$. This term is called *evolutionary nonlinearity.* It determines the change in internal energy of SB due to the motion energy [11] [13]. If the field of external forces is uniform or if the rigid body approximation is valid, the evolutionary nonlinearity disappears and Equation (4) is reduced to Newton's motion equation. If the friction force reaches the value of the active force, Equation (4) is reduced to Aristotle's motion equation. But if the SB's motion equation is derived in a standard way by summarizing the MP's motion equations [3], then the evolutionary nonlinearity will disappear.

Thus, the dissipation necessary for the emergence of attractors is possible only for SB. This means that if matter arose by evolutionary means, then according to the laws of classical mechanics, matter represents an infinite hierarchy of SBs nested within each other [11].

3. Motion Energy and D-Entropy

The SB's motion equation takes into account that the work of external forces goes not only to move the body, as is the case with Newton's motion equation, but also to change the body's internal energy. It follows that the dynamics and changes in the state of SB are determined not by one, but by two quantities [4]. The motion energy determines the motion of SB. But to determine the evolution of SB associated with a change in internal energy, in addition to the motion energy, we also need a quantity that would determine the internal state of SB. In thermodynamics, this is entropy. At first glance, entropy can be used here. But that's not true. The impossibility of its use is associated only with the fact that it is defined for motionless bodies close to equilibrium, or when their motion does not affect internal states [4] [15]. Therefore, for SB it is necessary to introduce a different, albeit entropy-like, quantity that determines the change in the internal state as a result of the motion of SB in a non-uniform field of forces. This value must be determined by the dynamic parameters SB in accordance with the second term of Equation (4). It was called D-entropy, and is determined by the ratio of the increment in internal energy SB to its total value. Thus, for D-entropy we have [14] [16]:

$$\Delta S_N^d = \Delta E_N^{int} \Big/ E_N^{int} \tag{5}$$

The SB's motion energy can be put in correspondence with the measure of "*Order*", since it characterizes the measure of ordered motion. In the internal energy SB should be put in correspondence with the measure of "*Chaos*", since it determines the measure of the chaotic motion of the elements of SB. Thus, D-entropy determines the connection between "*Chaos*" and "*Order*". A sufficiently large equilibrium system can always be represented by a set of equilibrium SB that are motionless relative to each other. In the particular case of body motion with friction, D-entropy determines the heating of each SB. That is, D-entropy characterizes the transformation *of* "*Order*" into "*Chaos*" and thereby characterizes the processes of evolution of bodies.

D-entropy, unlike thermodynamic entropy, is applicable for any number of elements of SB [19]. For small SB, D-entropy can be negative. For example, calculations have shown that the internal energy of an oscillator can be converted into motion energy [17]. But already at $N_1 > 100$, D-entropy only increases. When $N_2 > 10^3$, D-entropy stops growing with increasing number N. This is consistent with the fact that the coefficient of friction does not depend on the volume of the body. That is, the number N_2 - 10^3 determines the range of applicability of the thermodynamic description SB. Note that a similar result was obtained within the framework of statistical physics [18]. In general, these critical numbers depend on the substance and conditions.

4. D-Entropy and Motion Energy for Open Nonequilibrium Dynamic Systems

All bodies are open. Otherwise, they would not have arisen. The fact that in the general case all bodies can be represented as an ensemble of SBs, moving relative to each other, means that they are nonequilibrium. The fact that all bodies, to one degree or another, have the motion energy, suggests that dynamics is their defining state. Therefore, all natural objects can be classified as open nonequilibrium dynamic systems (ONDS).

In the approximation of local thermodynamic equilibrium, with a sufficient degree of generality, the ONDS can be represented as a set of equilibrium subsystems of potentially interacting MPs moving relative to each other [15]. Each subsystem moves in a non-uniform field of external forces and forces created by other subsystems. In the absence of external forces, the ONDS comes to equilibrium. It is determined by the equality to zero of the relative velocities of the subsystems [4]. For a closed nonequilibrium system, the change in D-entropy is determined by the sum of increments in the internal energy of its subsystems due to the energies of their relative motion. The increment of D-entropy of the ensemble has the form [16] [19]:

$$\Delta S_N^d = \Delta E_N^{int} / E_N^{int} = \sum_{L=1}^{R} \left\{ N_L \sum_{k=1}^{N_L} \left[\int \sum_s F_{ks}^L v_k \mathrm{d}t \right] \Big/ E_L \right\} \tag{6}$$

E_L is internal energy; F_{ks}^L is force acting on k-th particles of one subsystem from particles s-th of other subsystems; s is an external particle in relation to L is subsystem interacting with its k-th particles; v_k is speed of k-th particle; N_L is number of particles in L-th subsystems; $L = 1, 2, 3, \cdots$; R is the number of subsystems in a system.

To identify the patterns of SB motion in a non-uniform force field, numerical calculations of the dependence of fluctuations of the internal energy of SB from the number of MPs, based on Equation (4) were performed [11] [17]. To do this, we took SB with a different number of potentially interacting MPs, ranging from 2 to 1024, with a given value of internal energy and the motion energy of the center of inertia. The coordinates and velocities of the MP were set randomly so that their sum was equal to zero in the center of inertia system. The passage of

SB through a potential barrier in the form of a semi-sinusoid, the height of which is less than the kinetic energy of the center of inertia of SB, was considered. For each number of MPs in the SB, calculations of the SB passage of barrier were performed 400 times. In this case, the initial distribution of MP was set randomly, but so that it satisfied the Maxwellian distribution. The average amplitude of internal energy fluctuations when the system passes a barrier was determined depending on the number of MPs. It turned out that this dependence obeys the law:

$$\delta E^{int} \sim 1/\sqrt{N} \tag{7}$$

The same law is known in statistical physics [4]. But here the Equation (7) is determined by the deterministic motion equations. This is also consistent with the fact that the principle of maximum entropy of an equilibrium system corresponds to the principle of least action [4] [11]. That is, the fundamental laws of physics determine the scope of application of statistical laws, which can be considered as valid simplifications convenient for analyzing the dynamics of systems.

Let us show using Equation (4) that the establishment of equilibrium in closed systems, which are an ensemble of interacting equilibrium subsystems, occurs due to the transition of the energy of the relative motion of the subsystems into their internal energy [19].

Let be E^{tr} the energy of relative motions of subsystems. According to Equation (4), part of it ΔE^{tr} will turn into internal energy over some time. In this case, the quantity ΔE^{tr} is determined by a bilinear term of the second order of smallness. Note that in statistical physics the quantity ΔE^{tr} also has a second order of smallness [4]. From here we can write: $\Delta E^{tr} \sim \chi^2$, where χ is a small parameter, for example, a change in internal energy. If $\Delta E^{tr}/E^{int} \ll 1$, then the imbalance of subsystems during their interaction can be neglected. Then the reverse transformation of the internal energy of the equilibrium subsystem into the energy of its motion is impossible due to the conservation of the momentum of the system at rest.

Let now the interaction forces of subsystems or their gradients be sufficiently large. In this case, the equilibrium of the subsystems will be disrupted, and they will represent a set of equilibrium subsystems moving relative to each other. Then, to increase the internal energy of the subsystems, we write:

$$\Delta E^{tr} = \Delta E^{tr}_{ins} + \Delta E^{h},$$

where ΔE^{tr}_{ins} is the energy of the relative motions of the subsystems, ΔE^{h} and is the increment in the internal energies of the subsystems. This means that $\Delta E^{tr}_{ins} < \Delta E^{h}$. Energy ΔE^{h} cannot be converted into the energy of motion of subsystems. Therefore, we will proceed from the requirement that only ΔE^{tr}_{ins} can return to the energy of their motion. Let us denote the reverse flow of internal energy of subsystems as ΔE^{tr}_{ret}. According to Equation (4), the value ΔE^{tr}_{ret} is determined by a bilinear function of micro- and macrovariables of the second

order of smallness. And since $\Delta E^{tr} \sim \chi^2$, we will have $\Delta E^{tr}_{ret} \sim \chi^4$. Thus, the return flow of the internal energy of the subsystem into the energy of its motion cannot be more than the fourth order of smallness. Hence, the energy balance of the system is determined by the expression [14]:

$$\Delta E^{tr}_{dec} \approx \alpha\chi^2 - \beta\chi^4 \tag{8}$$

Here α, β are constants defined by Equation (4). That is, the increase in D-entropy of a closed nonequilibrium system is always positive, which proves our statement.

The entropy for ONDS can also be obtained using the distribution function, $f_p = f_p(r, p, t)$, which is a solution to the extended Liouville equation [20]:

$$\mathrm{d}f_p/\mathrm{d}t = \partial f_p/\partial t + \sum_{i=1}^{N}\left\{v_i\left(\partial f_p/\partial r_i\right) + \dot{p}_i\left(\partial f_p/\partial p_i\right)\right\} = -f_p\sigma \tag{9}$$

Here $i = 1, 2, 3, \cdots, N$ is subsystem number, F_i^p are forces acting on i-th subsystem, p_i is impulse of the subsystem, $\sigma = \sum_{i=1}^{N}\partial F_i^p/\partial p_i$.

Equation (9) is derived from Equation (4) in the same way as the canonical Liouville equation is derived from Newton's motion equation. It differs from the canonical Liouville equation in that the phase volume SB is determined not only by the motion energy, but also by the internal energy. In accordance with Equation (4), the magnitude of the change in the distribution function is proportional to the gradients of external forces. For a closed nonequilibrium system, the value σ decreases with a decrease in the energy of the relative motions of the subsystems due to its transition into the internal energy of the subsystems.

From Equation (9) it follows that the contribution to the change in function $f_p = f_p(r, p, t)$ introduce non-potential forces. The formal solution of Equation (9) can be written as follows:

$$f_p = f_p^o \exp\int \sigma \mathrm{d}t\,. \tag{10}$$

Function $f_p = f_p(r, p, t)$ obtained taking dissipation into account.

For systems close to equilibrium, the Boltzmann formula is valid: $S^B = -\int\left(f_p \ln f_p\right)\mathrm{d}p\mathrm{d}q$. From Equation (10) it follows that if $\sigma = 0$, then we have: $\mathrm{d}S^B/\mathrm{d}t = 0$. As one would expect, S^B it has a maximum when the ensemble reaches equilibrium.

5. The Principle of Relativity of Motion Energy and D-Entropy

Let us consider the general case when, in accordance with the condition of infinite divisibility of matter, the ONDS is a hierarchy of subsystems nested within each other. In accordance with PDS, the total energy of the ONDS can be represented as the sum of the motion energy and internal energy for each hierarchical level. In this case, the work of external forces changes both of these types of energy. That is, the internal energy at each hierarchical level of the ONDS should be divided into the sum of the energies of the relative motions of its elements and the sum of changes in their internal energies. And the change in the

internal energy of each hierarchical level of the ONDS determined by D-entropy. This means that the motion energy that went into changing D-entropy at the previous hierarchical level of matter already consists of an increase in the motion energy of the elements of the lower hierarchical level and increments of internal energies of elements of a given level. Let's call this *the principle of relativity of energy and D-entropy* for the steps of the hierarchical ladder of ONDS.

Let's imagine ONDS in the form of a chain of hierarchical steps $L_1, L_2, L_3, \cdots, L_{S-1}, L_S$. Moreover, the elements of each L_i hierarchical level is L_{i+1} a stage. This model corresponds to the fact that anybody consists of molecules, molecules consist of atoms, and so on.

Let's consider how the energy of the ONDS changes when external forces work over time Δt. In general, external forces can change energy at all hierarchical levels of the ONDS. An example is solar radiation. It not only heats the atmosphere, but also excites its molecules and atoms. In practice, as a rule, external influence directly changes the energy of the adjacent stage. For example, when a meteorite falls in the atmosphere or when a body rolls down an inclined surface due to friction and heating, their motion energy and internal energy change, but the states of the molecules and atoms are preserved. Here we limit ourselves consideration of the case when the work of external forces changes the state of the adjacent level of the ONDS. Let it be equal $\Delta_- E_0 = \Delta_+ E_1^m + \Delta_+ E_1^{in}$. The indices "*m*" and "*in*" mean the energies of motion of the elements and their internal energies, respectively; the signs "–" and "+" correspond to the loss of energy of the upper level and the gain of energy of the lower level; $\Delta_- E_0$ -the total work expended on changing the energy of the first hierarchical level L_1 for time Δt. Moreover $\Delta_+ E_1^m$, is increase in the motion energy of elements, and $\Delta_+ E_1^{in}$ is an increase internal energies and elements.

Let us take into account that over time Δt, dissipative processes occur at hierarchical levels, as a result of which the motion energy of each level goes to the lower level. Let as a result of dissipation at the level L_1 over time Δt, energy has gone to the lower level: $\Delta_- E_1^m = \Delta_+ E_2^m + \Delta_+ E_2^{in}$. Reduced energy of motion at the level L_2 has the form: $\Delta_- E_2^m = \Delta_+ E_3^m + \Delta_+ E_3^{in}$. The increment of energy at each hierarchical level over time Δt is determined by the balance of incoming and outgoing energy. Then we have: $\Delta E_{i+1} = \Delta_- E_i^m - \Delta_- E_{i+1}^m$. Corrections above the quadratic degree of smallness are not taken into account here. Also not taken into account are small terms that are associated with the reverse transformation of the energy of the lower hierarchical level to the upper hierarchical one level.

For each hierarchical level, the increment of D-entropy and is determined by the expression: $\Delta S_i^d = \Delta_+ E_i^{in} / E_i^{in}$. That is, it is determined by the ratio of the increment of internal energy to the total value of internal energy at a given hierarchical level due to the dissipative loss of motion energy of the upper hierarchical level. The disequilibrium of each hierarchical level is determined its motion energy. Her and change is determined by the condition: $\Delta E_i^m = \Delta_+ E_i^m - \Delta_- E_i^m$.

In accordance with the definition of negentropy, the change in its value at

each hierarchical level is determined as follows: $\Delta W_i^{NE} = \Delta_+ E_i^m / E_i^m$.

The stationarity of the ONDS is determined by the fact that at each hierarchical level the following condition holds: $\Delta E_i^m = \Delta_+ E_i^m - \Delta_- E_i^m = 0$. That is, for the stationarity of the ONDS it is necessary that the negentropy at all its levels compensated for the dissipation of motion energy.

Here, when calculating the energy balance, ONDS is taken into account not all its determining factors. In particular, the energy influx will be compensated by Planck radiation [15]. In this case, a complete description of the energy balance of the ONDS goes beyond the scope of classical mechanics. But in general, it can be argued that the motion energy and D-entropy make it possible to determine the state of the ONDS.

6. Conclusions

Description of evolutionary processes becomes possible after eliminating the contradictions between classical mechanics and thermodynamics. This contradiction lies in the reversibility of the dynamics of bodies and the irreversibility of internal processes caused by the dynamics of their elements. The contradiction is eliminated as a result of the use in classical mechanics of a new principle of symmetry dualism, and the construction of the SB motion equation on its basis. Thanks to this principle, it is built taking into account the fact that the work of external forces goes not only to change the SB motion energy, but also to change its internal state. The SB motion equation follows from the condition for the fulfillment of the law of conservation of total energy, represented by the sum of the motion energy and internal energy SB in independent micro- and macrovariables.

According to the SB's motion equation, a description of evolution becomes possible if we rely not only on the concept of motion energy as a measure of "*Order*", but also on the concept of D-entropy, which determines the increase in the measure of "*Chaos*" as a result of the transformation of motion energy into internal energy. Thus, the evolution of bodies is determined by two quantities. These quantities include the motion energy and D-entropy. D-entropy characterizes the internal state of a moving body and depends on the body's motion energy, its internal structure, and is expressed through micro- and macrovariables.

For comparison, we note that the state of the system in the thermodynamic approach is also determined by two quantities that are not related to the body's motion. This is the internal energy of the body and its entropy. A distinctive feature of D-entropy is that it takes into account the role of the dynamics and interaction of bodies in changing their internal states. This is precisely what allows it to be used along with the motion energy to describe evolutionary processes.

According to the hierarchical organization of matter, due to its infinite divisibility, an increase in D-entropy at the corresponding hierarchical level goes to the energy of the relative motions of the elements of a given level, and to an in-

crease in their D-entropy. For the steps of the hierarchical ladder of matter, the *principle of relativity of energy and D-entropy* applies.

Fund

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Prigogine, I. (1985) From Being to Becoming. Nauka, Moscow, 328.

[2] Lanczos, C. (1965) The Variational Principles of Mechanics. Mir, Moscow, 408.

[3] Goldstein, H. (1975) Classical Mechanics. Nauka, Moscow, 416.

[4] Landau, L.D. and Lifshitz, E.M. (1976) Statistical Physics. Nauka, Moscow, 584.

[5] Landau, L.D. and Lifshitz, E.M. (1979) Physical kinetics. Nauka, Moscow, 528.

[6] Zaslavsky, G.M. (1984) Stochasticity of Dynamic Systems. Nauka, 273.

[7] Fröhlich, J. (2022) Irreversibility and the Arrow of Time. In: *Standalone Titles*, EMS Press, Berlin, 401-435. https://doi.org/10.4171/90-1/17

[8] Kuzemsky, A.L. (2019) Irreversible Evolution of Open Systems and the Nonequilibrium Statistical Operator Method.

[9] Maes, C. and Netocny, K. (2003) Time-Reversal and Entropy. *Journal of Statistical Physics*, **110**, 289-310. https://doi.org/10.1023/A:1021026930129

[10] Somsikov, V.M. (2016) Transition from the Mechanics of Material Points to the Mechanics of Structured Particles. *Modern Physics Letter B*, **4**, Article ID: 1650018. https://doi.org/10.1142/S0217984916500184

[11] Somsikov, V.M. (2021) Fundamentals of Physics of Evolution, Almaty, Kaz. Nu Al-Farabi, 335.

[12] Wigner, E. (1966) Symmetry Breaking in Physics. *UFN*, **89**, 453-466. https://doi.org/10.3367/UFNr.0089.196607e.0453

[13] Somsikov (2014) Limitation of Classical Mechanics and Ways It's Expansion. PoS (Baldin ISHEPP XXII-047). September JINR, Dubna, 1-12. https://doi.org/10.22323/1.225.0047

[14] Somsikov, V.M. (2023) "Order" and "Chaos" in the Evolution of Matter. In: 15*th Chaotic Modeling and Simulation International Conference*, Springer, Berlin, 339-351. https://doi.org/10.1007/978-3-031-27082-6

[15] Rumer, Y.B. and Rivkin, M.S. (1977) Thermodynamics. Statistical Physics and Kinetics. Nauka, Moscow, 532.

[16] Somsikov, V.M. (2021) D-Entropy in Classical Mechanics. In: Skiadas, C.H. and Dimotikalis, Y., Eds., 14*th Chaotic Modeling and Simulation International Conference. CHAOS* 2021, Springer, Cham, 481-493. https://doi.org/10.1007/978-3-030-96964-6_33

[17] Somsikov, V.M. and Andreev, A.B. (2015) On Criteria for the Transition to the Thermodynamic Description of the Dynamics of Systems. *High School Physics*, **58**, 30-39. https://doi.org/10.1007/s11182-016-0677-z

[18] Aringazin, A.K. and Mazhitov, M.I. (2003) Quasicanonical Gibbs Distribution and Tsallis Non-Extensive Statistics. *Physica A*, **325**, 409-425. https://doi.org/10.1016/S0378-4371(03)00253-X

[19] Somsikov, V.M. (2017) Non-Linearity of Dynamics of the Non-Equilibrium Systems. *World Journal of Mechanics*, **7**, 11-23. https://doi.org/10.4236/wjm.2017.72002

[20] Somsikov, V.M. (2004) The Equilibration of a Hard-Disks System. *IJBC*, **14**, 4027-4033. https://doi.org/10.1142/S0218127404011648