I. SELF-ORGANIZING PROCESSES IN DIFFERENT-NATURE SYSTEMS

Self-organizing processes play an extremely important role in the surrounding life, i.e. in the phenomena occurring in the living and lifeless nature. One can hardly solve a variety of medical, biological, technological problems without studying such processes since the main goal of synergetics (i.e. the science which studies self-organizing systems) is to reveal the general regularities of self-organizing processes in different-nature systems (Mar'yan & Szasz, 2000).

1.1. Synergetics: principal definitions

Synergetics covers today not only various areas of science, featuring processes of self-organization in an alive and lifeless nature, but also permeates into various fields of human activity. The professor of Stuttgart University and the Director of the Institute of Theoretical Physics and Synergetics H. Haken is recognized as the author of the term "synergetics" (Haken, 1985). According to Haken, synergetics studies the behavior of the systems comprising a great number of subsystems (parts, components). In its precise sense, the term “synergetics” means the joint action, distinguishing, thus, the coordination in the functioning of the parts, reflected in the behavior of the system as a whole [1].

The advantage of synergetics just is that the systems, representing the subject of their study, and considered as a whole, can be of the most different nature and be studied by each of sciences separately (for example, by physics, biology, chemistry, mathematics, sociology, economy and so on). Each of such sciences studies its “own” nature of the system by its intrinsic methods and produces the results of

[1] The predecessor of Haken's synergetics was that of the physiologist Sherington, who studied the consistent action of flexors and extensors at limb operation, as well as the synergy, i.e. junction of a man and God in a pray.

research in it’s “own" language. At the existing differentiation of the science, this means in that the achievements of one science frequently become inaccessible to the attention and comprehension of the representatives of other sciences. A similar situation takes place with interfacing sciences originating from the junction of two sciences in a more or less wide frontier field (for example, in biophysics, physical chemistry and so on). So, physics studies a physical nature of the systems by physical methods, biophysics is engaged in the research of biological objects by physical methods. Therefore, contrary to the traditional areas of a science, synergetics is interested in common legitimacies of the evolution of the systems of any nature, which stipulates its generalized interdisciplinary character.

Synergetics studies a common character of regularities and dependences, not appealing to a nature of systems, by means of its specific resources, having a common character in relation to private sciences. The unity and the integrity of synergetics in studying the systems are illustrated by Fig. 1.1.1.

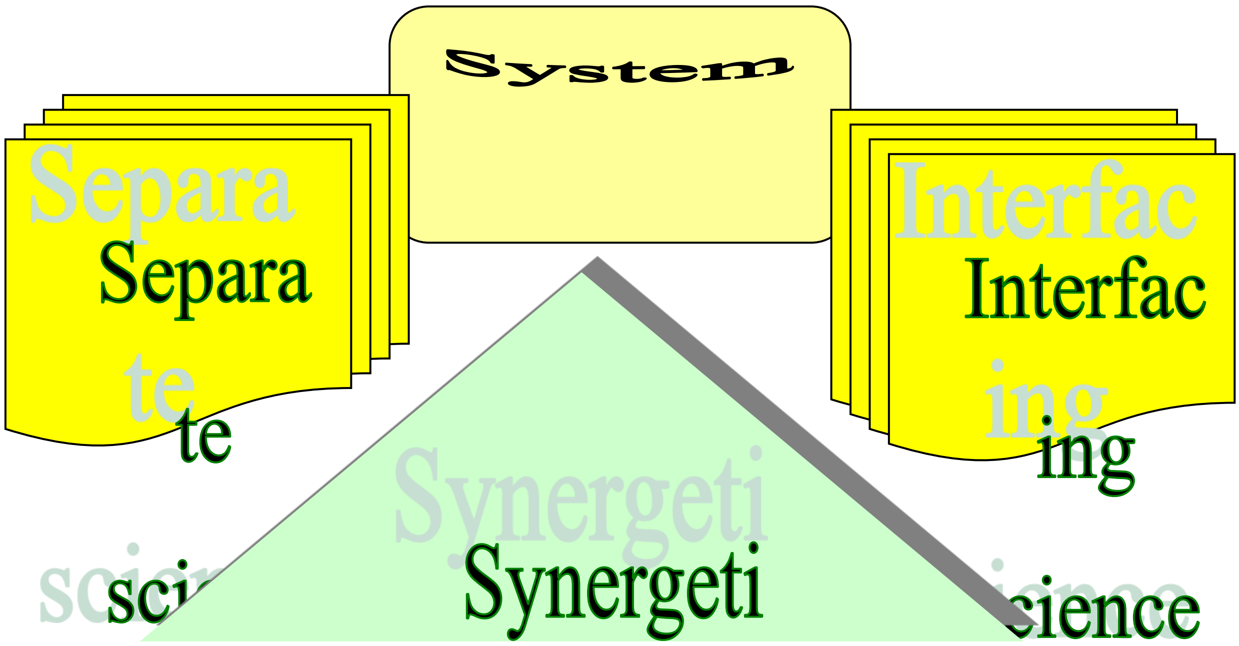

Fig. 1.1.1. Synergetics as interdisciplinary field of science.

Due to that synergetics tears away a specific nature of investigated systems, it acquires an ability to describe the formation development, by working out a common model of phenomena occurring in an organic and inorganic nature.

1.1.1. Synergetics and self-organizing processes

Synergetics appears to be a link in understanding relationship between the substance and the life. The most apparent feature of the objects of an alive nature is that they are capable of self-organization, i.e. the spontaneous formation and development of complicated structures. The necessary premise for the self-organizing effects consists in an openness of systems (energy, mass, information exchange with environment). Due to this flux from outside, the system becomes active, i.e. gaining an ability of the spontaneous formation of the structures. Apparently, the effects of self-organization cannot be an exclusive property of biological objects, and, thus, they are also observed (in simpler form) in the systems of an inorganic origin.

So, synergetics combines the studies of the system as a whole and those of its separate parts at different levels. It makes a bridge between them by two levels of description, due to their coordination, synchronization and coherence. Therefore, the system acquires the properties, not inherent in its separate parts. This circumstance has an essential importance and allows one to define synergetics as a science exploring the self-organization. Thus, the macroscopic manifestations of the processes occurring at the microscopic level arise "independently", due to self-organization, with no "guiding hand", that operates outside the system. The self-organization is born by the system itself as a result of a loss of stability of the state. Thus, self-organization is reduced to the selection among the spatially active systems, potentially possessing a great number of degrees of freedom at a small number of order parameters (variables) defining the dynamics of the whole system. A small amount of order parameters and scarce possibilities, which they reflect in defining separate states, testify to the fact, that in compound systems only a few structures are possible and available being consistent through a combined action of the elements (Yurkovych, Seben & Mar'yan, 2017).

There are no separate control elements (units) of the system, being in charge of a certain property. The complicated structural formations in the nature are simultaneously both determinate (predictable) and stochastic (unpredictable), i.e. they exhibit a dualism of determinate and stochastic. In synergetics, there is nothing predetermined at a level of present computer program – except the structures and systems, which at a loss of stability can give rise to some new states. The system becomes unpredictable not by virtue of our ignorance, but by virtue of its non-local properties, such as complexity, non-linearity, openness, non-equilibrium. At a point of a loss of stability the new functioning mechanisms with new parameters are self-organized. It should be noted, that the parameters of the state do not disappear – they remain, but in cases related to the self-organization the system selects the order parameters itself. We obtain a sort of ready oblate information on the system. Even when the separate elements of the system have a complex internal structure, all their internal complexity is not revealed in their mutual interaction, and, from the point of view of a macro system, they function as simple enough objects with a small number of effective degrees of freedom (Mar'yan, 1998). Otherwise, no structure ordering occurs in the system.

It should be noted that it is possible to describe more or less adequately self-organizing phenomena at one level. The investigation of the phenomena between various levels is so far problematic. The chaos at one level leads to the structuration at the other level. This approach is one of the basic in synergetics. The thermal oscillations and diffusion act as the chaos at the micro level. However, for a number of self-organizing systems of organic and inorganic origin this process plays a principal role in the formation of ordering at the mezo scoping (average) level order. The chaos at one level results in the self-organization and appearance of an order parameter at the other level (spatial or temporary). The systems behave in a chaotic manner, however at the particular stages of the process or at some characteristic moments they result in the appearance of the formations, for which the structural representation is adequate. Such structures can be considered as those of the next level with their definite functioning parameters. At the next level the ordering may arise again, and so on.

Convenient images of non-linear dynamics are the fractal structures (Mar'yan & Yurkovych, 2015), for which the description obeys the same rules with the change of spatial or temporary scales. The term "fractal structures" is widely used for the description of self-organization in the energy, mass, and information – open systems, since in this case in the non-linear dynamics tasks we do not deal with unstructured random processes, but just with the results of self-organization, i.e. the creation of complex, coherent structures (Yurkovych, Seben & Mar'yan, 2017).

Synergetics describes the birth and creation of spatially and temporally branched structure under the scripts of interchanging periods of stability and instability. At the initial stage the system, wandering in the state space, forms at certain controlling parameter values the first attractor (attractor is the steady state, to which the system tends and for which the predictability and reproducibility of the modes are peculiar). Then, skipping due to a loss of stability and fluctuations into the other domain, it forms a second attractor, and so on. Due to this the contour of the states of the system – i.e. the domain of stability, singular points, and tunnels of transitions from one domain to another – is formed. The concept of a path of self-organization of the complex system arises, being convenient to be described by the fractals. The task of synergetics consists in the search for the studies of the models of self-organizing systems, which result from the most typical assumptions, the properties of separate active elements and the laws of interaction between them.

1.1.2. Methods of the synergetics

The theory of dissipative structures, the Thom's theory of catastrophes and the theory of mappings and attractors belong to the most spread synergetic methods (see Fig. 1.1.2).

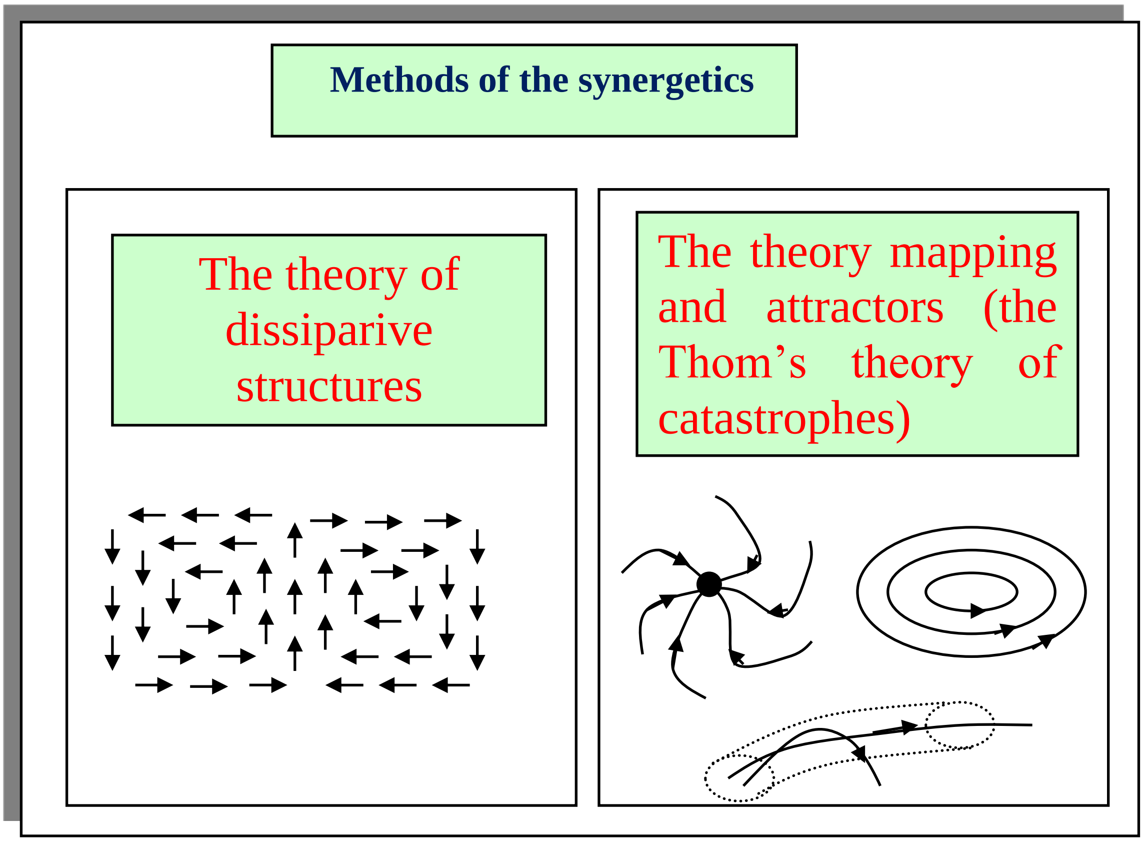

Fig. 1.1.2. Methods of synergetics.

Consider the above methods.

1.1.3. Dissipative structures: general characteristics

G. Haken (Haken, 1985) was among the first who has drawn an attention to the commonness of dissipative structure formation process with the phase transitions in non-equilibrium systems (in ferromagnetic, ferroelectrics, superconductors, etc.). This allowed him to call the dissipative structure formation processes the non-equilibrium transitions. The latter are much more diversified than the equilibrium ones and play a prime role not only in the physical processes but also in biological and chemical processes.

The notion of dissipative structures as one of the most general notions of thermodynamics of non-equilibrium processes was first introduced by I. Prigogine (Nicolis & Prigogin, 1989). This term emphasizes the fact that these structures arise in dissipative systems during the non-equilibrium (irreversible) processes. The temporal, spatial and spatial-temporal dissipative structures are distinguished.

Note the necessary conditions for formation of the dissipative structures.

- Dissipative structures can be produced only in the open systems. In such systems, the energy influx or the matter exchange may occur compensating the losses and providing the existence of the ordered states. In this connection, the external supply of the "negative entropy" does exist together with the entropy production.
- Dissipative structures arise in the macroscopic systems comprising a large number of particles (atoms, molecules, cells, university etc.). This allows one to apply the equations for the functions averaged over the physically infinitesimal volume (the local equilibrium condition). The ordering in these systems is also of co-operative character, since a great number of objects are involved in it.
- Dissipative structures arise only in the non-linear systems described by the non-linear function.
- To admit the occurrence of dissipative structures the linear equations must allow (at certain values of parameters) the appearance of the solutions with other symmetry, for instance, the transition from the laminar flow to the turbulent one accompanied by the change in its velocity.

However, a principal difference exists between the appearance of the order via the fluctuations in the systems far from the equilibrium and that in the living systems. This difference is that in the first case we deal with the process of dissipative structure self-organization, whereas in the second case the self-regulating phenomenon occurs which provides the stability of the state of the biological system far from the equilibrium. In the first case the cause/effect relations are of a spontaneous type, while in the second case they are strictly determinate by the genetic program. So, dissipative systems are non-linear and, taking into account the necessity to be general as much as possible, we may consider them in a common mathematical model (Mar'yan, 1998).

The non-linearity of the problem under study motivates the possibility of a qualitative change in solutions, which describe the behavior of the system at the continuous variation of the parameters. In this case a slight variation of the system parameters may result in a considerable change in the solutions. The simplest example of non-linear equation is an ordinary quadratic equation. We can increase continuously one of the coefficients and find that at any small increment in the vicinity of some quantity both real solutions can be produced or vanish.

The models of the turbulent motion of liquids, the ecological models and the Belousov-Zhabotinsky reactions, formation of the non-crystalline materials are the recognized examples of non-linear processes (Mar'yan, Szasz, Szendro & Kikineshy, 2005). Non-linear dynamic systems may have extremely complicated motion modes, i.e., depending on the parameters; their dynamics may be either regular or chaotic. One of the paradoxical peculiarities of the systems specified by non-linear mathematical models is the property of self-organization. In complex systems with many interacting subsystems, the qualitative peculiarities may arise being not possessed by any component. As a result, a new structure and the relevant operation appear at the macroscopic level.

1.1.4. Dissipative structures of the active medias

Based on the examples considered above, one may distinguish three types of active media elements in which self-organizing processes are observed (Mikhailov & Loskutov, 1996): bistable, multivibrating (excited) and auto oscillating elements (Fig.1.1.3).

Bistable elements have two stationary states, and may stay in each of these states for an infinitely long time. An external action may cause the transition from one state to another. To induce the transition the intensity of this action must exceed a certain threshold level.

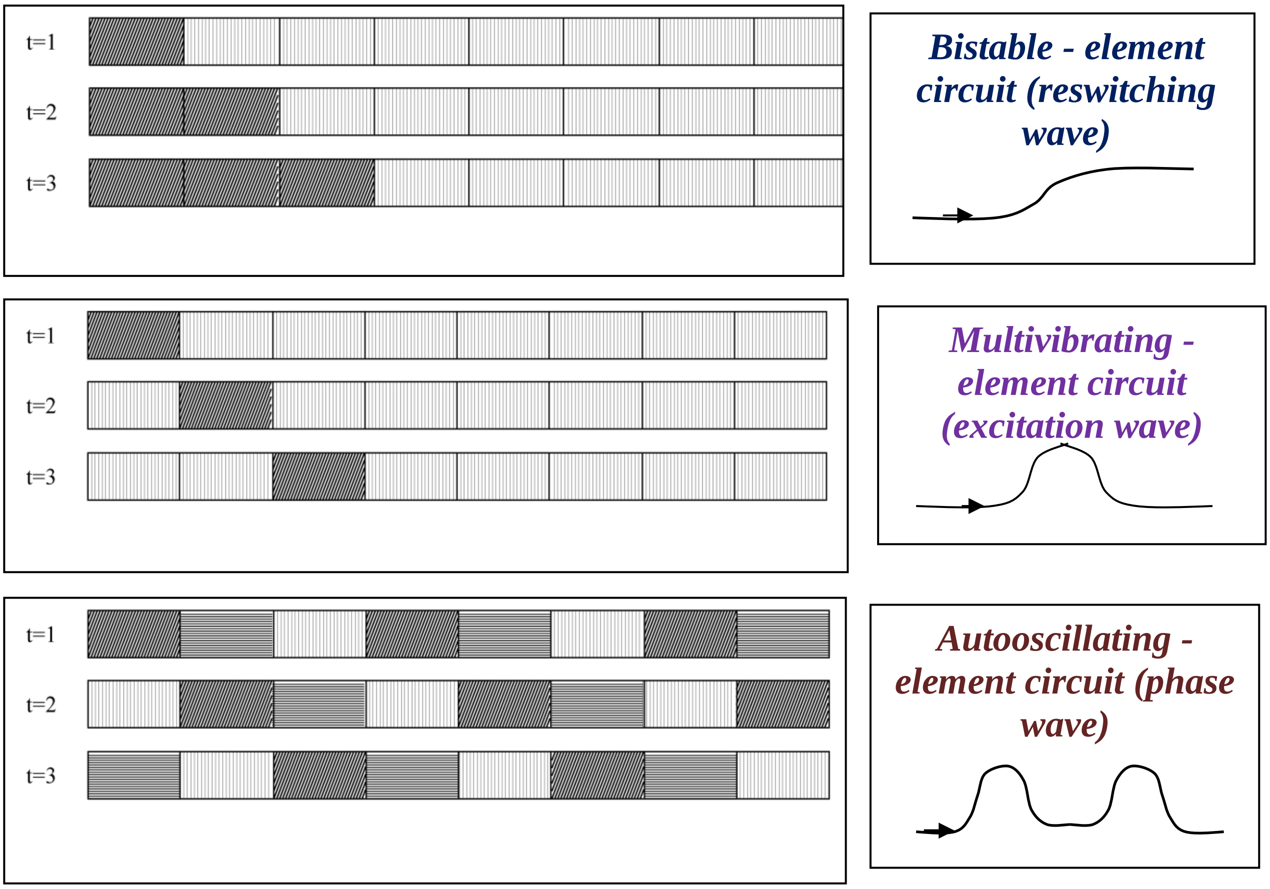

Fig. 1.1.3. Types of active media elements.

Multivibrating elements have a single distinguished rest state, which is stable with respect to comparatively weak external actions. However, such systems differ from passive ones by their response to the actions, exceeding the threshold level. As a response to this quite intense external action, the system produces the flash of activity, i.e. a certain sequence of active transitions takes place, and only after this the system returns to the initial rest state.

Auto oscillating elements act like the *perpetum mobile*. They perform autonomously cyclic transitions via a certain group of states. An external action is able to decelerate or accelerate this cyclic movement only, but not to stop it. The examples considered illustrate the basic properties of the produced stationary structures. First of all, each of these structures is a stable formation, the form and the size of which are resumed at slight perturbations. The same distributed system can possess a huge number of different stationary non-equilibrium structures. Which one of the stationary states is realized in experiment depends on the initial conditions and external random field. For such structures, besides the local interaction, the active medium elements are involved in the long-range feedback. The properties of dissipative structures set up in the medium depend tangibly on the type of elements composing this medium, i.e. bistable, excited or auto oscillating elements (Fig. 1.1.3).

If the active medium, in which self-organizing processes are realized, consists of the bistable elements, then it comprises a family of domains with $L_{bistable}$-order dimensions in which the state of the medium is close to one of two stable states of the separate element. These domains are separated by transient L-wide layers.

If the medium comprises the multi vibrating elements, then it possesses only a homogeneous stationary rest state. In the one-dimensional case, this structure is a set of narrow L_{multi} -wide strata spaced by $\sim L$ distances. In the domains between the strata, the medium is in the state lying close to the rest one. In two-dimensional or three-dimensional cases, the dissipative structure is an aggregate of little drops (Mar'yan & Szasz, 2000).

If one separate element of the medium undergoes periodic auto oscillations, then the stationary homogeneous state of the active medium is absolutely unstable.

Stationary structures are formed in it in the form of L_{auto}-long strata separated by transient layers (Fig. 1.1.3).

1.1.5. Levels of the formation of the dissipative structures in science education

The occurrence of dissipative structures away from the equilibrium is due to the presence of fluctuations and, therefore, it was called the "order via the fluctuations". That type of ordering is an essential approach to the conditions of the vital activities of biological objects, since the organisms are the open systems far from the equilibrium. Dissipative structures of the biological origin have been discovered at the various levels of complexity:

- at the molecular level, i.e. the variations of the substrate density during the reactions catalyzed by the ferments;
- at the cellular level, i.e. the induction-type vibrations and genome repressions described by Jacobi and Mono;
- at the organism levels (the circadian and similar rhythms);
- on the population level, i.e. the variation of a number of organisms within biogenesis. While in physic-chemical systems the feedback, similarly to autocatalysis, occurs extremely rarely, but it is a necessary condition for the biological organization in living systems (Mar'yan & Szasz, 2000).

The term “whole” in relation to the concept of dissipative structure is treated as the result together with its formation, distinguishing and combining, thus, the process of formation and the result. The dissipative structures in the objects of sciences education are not a constant notion, but are in a permanent formality.

The degree of steady integrity, which is peculiar to the dissipative structure as an organic whole at the mentioned above levels and necessary to promote the development of the structures at the higher level of organization, is determined by a minimum of energy dissipation (Babloyantz, 1986). Let's define fundamental dissipative structures as the result of self-organization at the appropriate molecular – organism levels. A quantitative measure of each level is the intensity of interaction with the medium external wish respect to a considered level that defines the binding energy of the produced stable system. The hierarchy of levels of structural organization ("a quantum ladder") is considered as a result of a prior self-organization (Fig. 1.1.4).

One may distinguish some stages of the formation of the dissipative structure

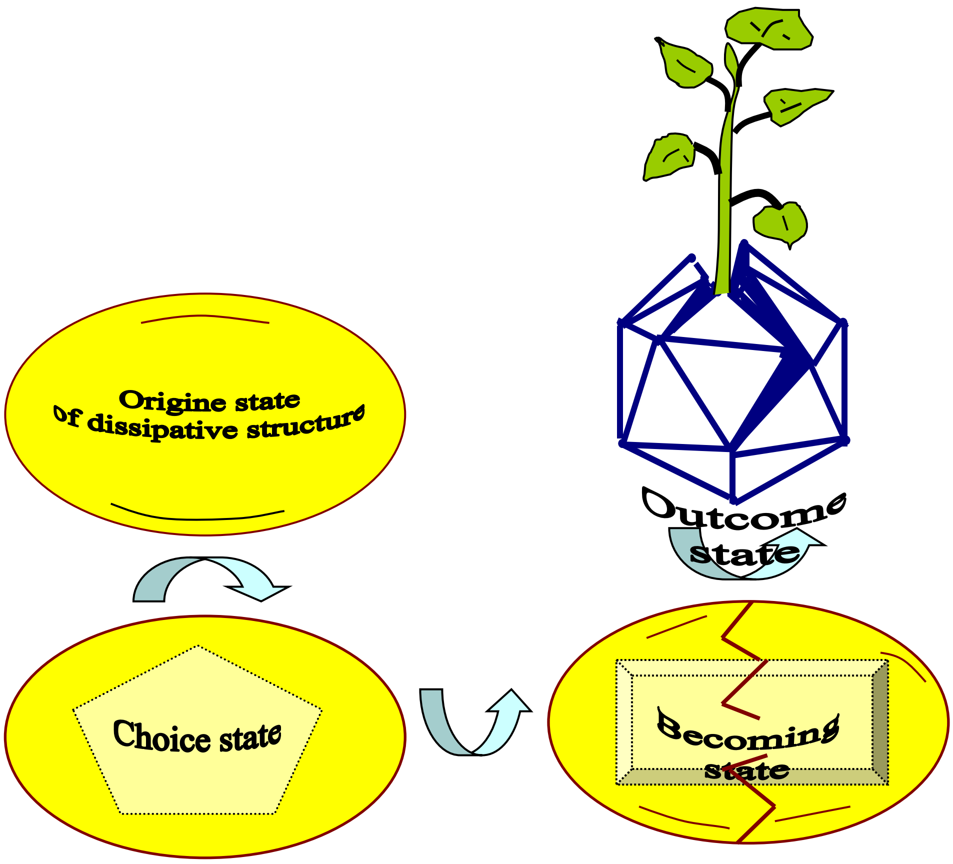

Fig. 1.1.4. Visual representation of the dissipative structure development in science education.

at certain levels (visually this process is illustrated in Fig. 1.1.4). The first stage describes the initial state, which comprises different possibilities of structuring the medium in the minimized (not evident) form. In the physical aspect, this stage is associated with that initial "vacuum", the fluctuations of which are potentially uniformly distributed over the whole system (see Fig.1.1.5). The second stage is defined by a state on the verge of possible and true, in which a set of principally essential and possible, but not yet stable structures, appear to be open. The third stage is related to a choice of the possibility of structural complication up to the formation. At the fourth stage, a manifestation and implementation of the stable structures occur.

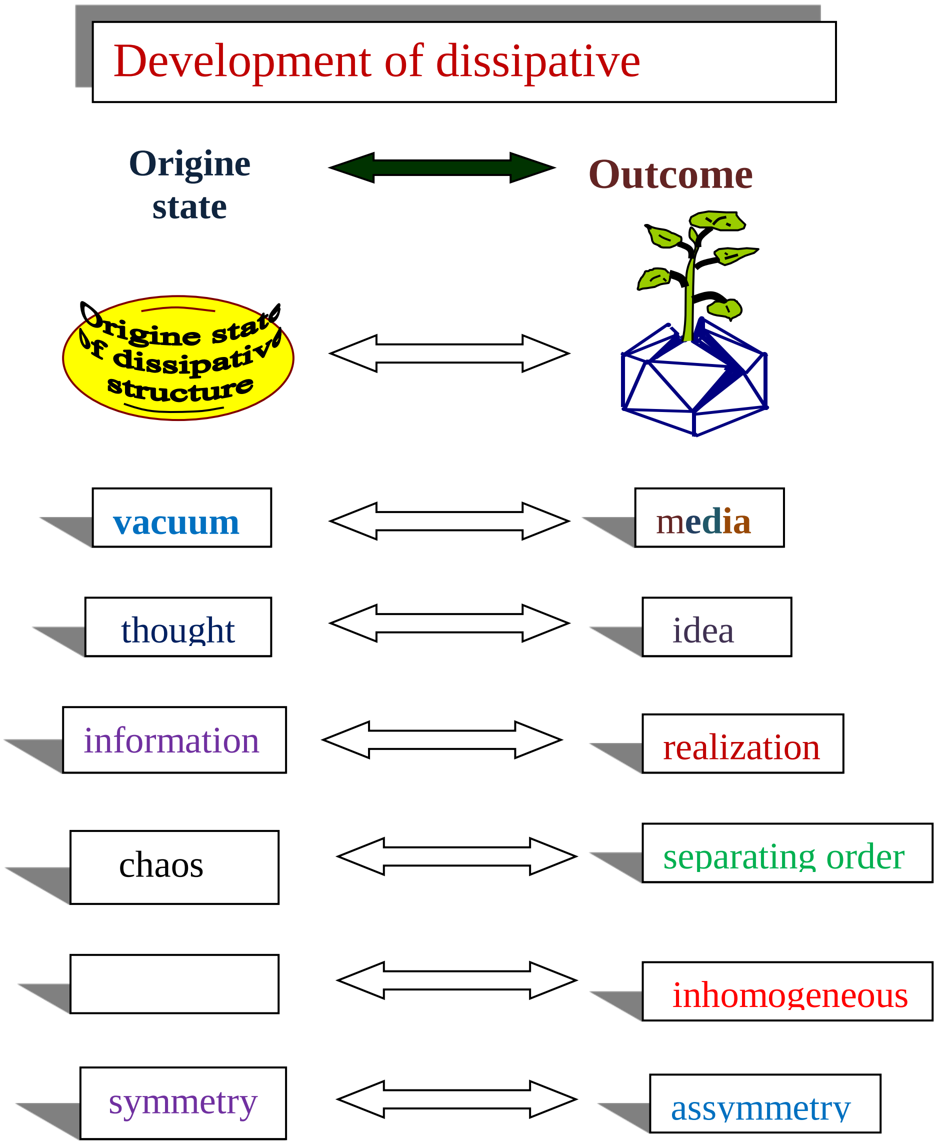

Fig. 1.1.5. Examples of the dissipative structure development in science education.

1.2. Self-organizing systems: information technology and science education

Recently much attention has been paid to the theoretical and experimental studies of self-organizing processes in various physical, chemical, biological and education systems. The processes are non-equilibrium and accompanied by the energy dissipation.

Many examples of the ordered states formation during non-equilibrium processes are known in physics. In this case the ordering may occur both in time (time dependence, e.g., the appearance of limiting cycles in auto-oscillating systems) and space (standing strata in gas discharges, the Benar's cells at the convectional movement in liquids, the transition of the laminar flow to the turbulent one in the liquid) (Nicolis & Prigogin, 1989). The formation of spatial-temporal ordered states (e.g., auto-wave processes in classic and quantum generators (lasers)) is also possible (Yurkovych, Seben & Mar'yan, 2017).

1.2.1. Non-equilibrium self-organizing processes in the systems of lifeless nature

The studies of self-organizing processes in condensed systems (i.e. liquids, crystals, glasses) and in information, biological objects, which receive the energy from the external sources, are characterized by a continuous energy dissipation and redistribution among active elements. When some of these elements are locally interlinked and form the distributed active medium, then the production of various stationary or time-dependent spatial structures is observed in this medium. Such fundamental notions as consistency, mutual action, ordering are the constituents of both physics and biology, sciences education, i.e. the possibility to describe the behavior of both living systems and common physical systems by using these notions is an outstanding achievement. For most cases the properties of the whole system cannot be explained on the basis of the simple superposition of the properties of its components, since these subsystems interact with each other. In addition, the system acquires the properties, which contrast qualitatively with those of separate subsystems. Such subsystems may be atoms, molecules, cells as well as the human communities, information technology (Mar'yan & Szasz, 2000).

First of all consider the self-organizing processes in physical systems. These processes in liquid (gaseous) layers at the presence of temperature non-homogeneities are known as the Benar's heat convection (Fig. 1.2.1). The heat convection provides the basis for various phenomena observed in nature. Among them there are atmospheric and ocean circulations, which define the climate change for a short or long period. Another example is the drift of continents or, in other words, the motion of continental platforms caused by the large-scale cloak movements. Heat convection underlies the heat and matter transfer inside the Sun, which defines substantially the solar activity.

The heat convection is also related to the production of the so-called Benar's cells in the liquid layer lying between two parallel planes to which the temperature gradient ΔT is applied: $\Delta T = T_2 - T_1 > 0$.

At low temperature gradients ΔT in the system, a single state is established for which the heat transfer from the lower layer of liquid to the upper one is specific and the latter transfers the heat to the environment providing the constant T_1 (Fig. 1.2.1). The temperature, as well as density and pressure, are not homogeneous, and due to the heat conduction vary almost linearly from the warm domain (T_2) to the cold one (T_1). In this state, reached by the system in a form of a response to the external restriction, the stability dominates. When the system deviates from the equilibrium with the increase of ΔT, at certain critical value ΔT_c the bulk of liquid starts to move. This motion will not be chaotic now. The liquid is structured in a form of cells noticed first by Benar and, thus, called the Benar's cells (Fig. 1.2.1). These cells are placed along the horizontal axis, and the liquid moves sequentially clockwise (R) and counterclockwise (L) inside them.

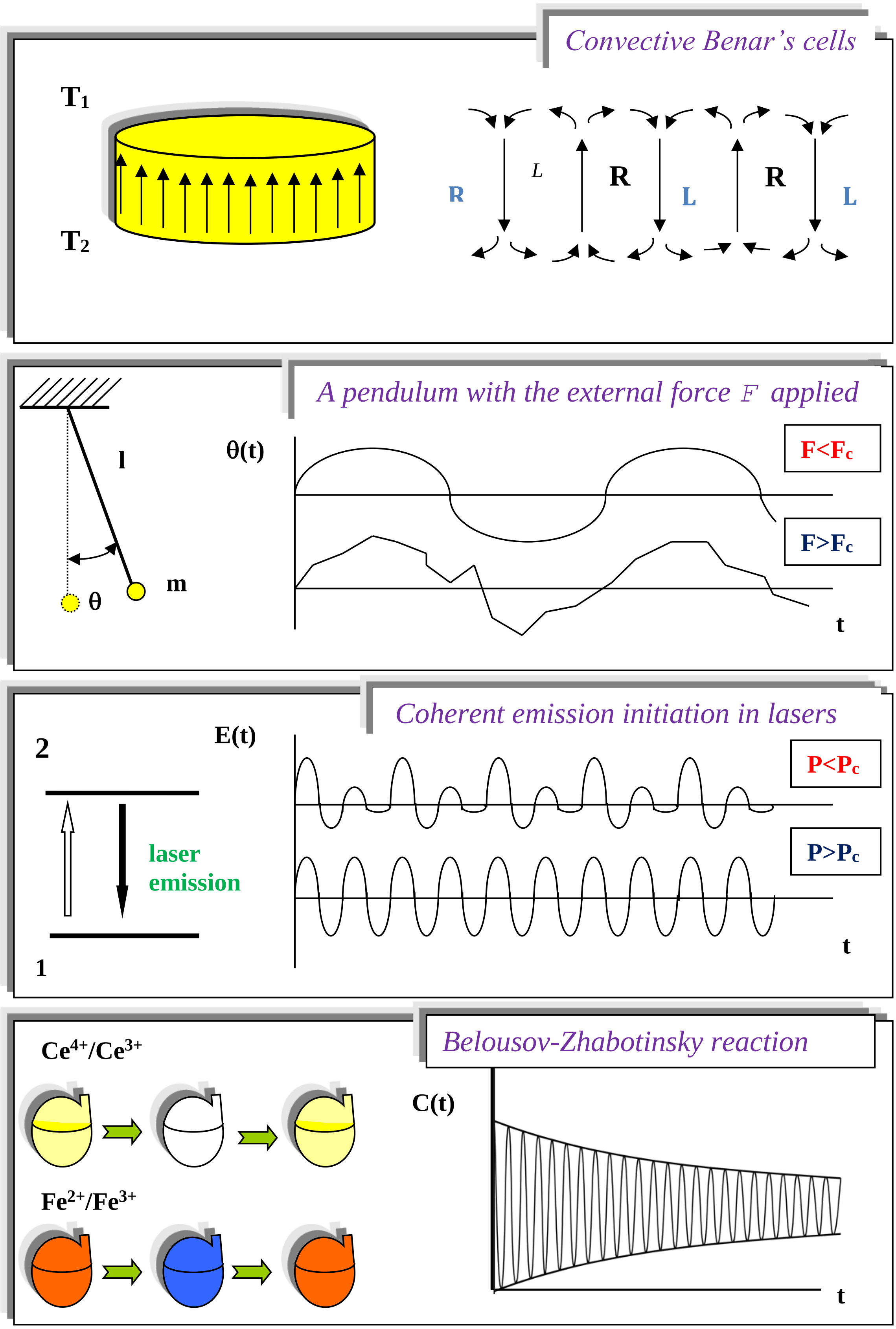

Fig. 1.2.1. Non-equilibrium self-organizing processes in the physical and chemical systems.

The qualitative explanation of this phenomenon resides in as follows. Due to the thermal expansion, the liquid is stratified, and that part of it, which is close to the bottom plane, possesses a lower density as compared to the upper layers. This causes the density gradient directed in the opposite to the gravity force direction. Evidently, such a configuration is unstable. Consider, for example, a small volume of liquid close to the bottom plane. Imagine now that this element of volume moves slightly upwards due to the perturbation. Entering a colder (and, thus, more dense) domain, the said element is a subject of the upward Archimedean force, which tries to enhance the motion. On the other hand, if the drop, which is first close to the upper plane, moves downwards, it enters the low-density domain and the resulting force of Archimedean and gravity forces will accelerate the downward movement. Therefore, in this liquid layer up- and downward fluxes may originate resulting in the cells production. The reason for which such fluxes are not observed at low ΔT is related to the stabilizing effect of the viscous liquid resulting in the initiation of internal friction forces directed against the movement. The heat conduction is also the stabilizing factor due to which the temperature difference between the displaced drop and its environment tries to escape. This, in particular, explains the occurrence of the symmetry violation and transition from the simple behavior to the complex one. The notions of ordering and consistency of the system are the specific features of such transitions. When ΔT is less than the critical value ΔT_c, the homogeneity of the liquid makes its different parts independent of each other. In contrary to this, each volume element above the threshold value ΔT_c affects the state of the other element. Such pattern implies the presence of correlations, i.e. the statistical dependence of remote parts of the system. Specific dimensions of the Benar's cells are within the millimeter region (10^{-1} cm), whereas the specific spatial scale of intermolecular forces lies within the Ångstrom region (10^{-8} cm), i.e. the Benar's cell involves almost 10^{21} molecules (Mikhailov & Loskutov, 1996). The fact that such a considerable amount of particles may demonstrate the coherent behavior, in spite of the random thermal motion of each part, is one of the principal properties, which characterizes the occurrence of the self-consistent behavior.

A specific feature related to the Benar's cells is that this laboratory experiment is characterized by the reproducibility, i.e. at $\Delta T = \Delta T_c$ the convective pattern arises. On the other hand, the liquid is structured into the clockwise and counterclockwise-rotation cells, which are the random quantities. Thus, aside from the determinability of the occurrence of the cell structure, the direction of motion in the cells is not predictable and uncontrollable. Only the case of one or another perturbation, which dominates at the given moment, defines the motion of the liquid in the cell. Thus, a peculiar combination of the accident and definiteness is seen. This analog dualism known in biology as a manifestation of fluctuations and natural selection is revealed in physics in the quantum-mechanical approach to the description of microscopic phenomena.

As a conclusion, in the case of remoteness from equilibrium, the system can adapt itself to external restrictions in the environment by different ways. From the mathematical viewpoint, in this situation at the same values of parameters one can obtain several different solutions. Only the chance defines which one of them will be obtained. The fact that among numerous possible variants one variant has been chosen, provides a system with the historical dimensionality, i.e. a specific memory about the former events, which have happened at the critical moment and defined the influence on the evolution.

At large $\Delta T = \Delta T_c$, the most suitable for heat transfer convection regime is established in the liquid (at ΔT_c the immobile heat-conducting liquid regime becomes unstable). The convection cells form more highly-organized structure, which results from the collective motion in the liquid.

The similar self-organizing processes are also specific for the occurrence of a coherent emission (Haken, 1985). In this case the transition of atoms to the excited state is induced by an external influence. These atoms act as a microscopic antenna (see Fig.1.2.1). At low pumping powers $P < P_c$ (P_c is the critical power value), atoms generate light packets independently of each other, and the laser is operating similarly to a common lamp (the radiation field $E(t)$ consists of separate uncorrelated packages). At $P > P_c$ powers, all the atomic antennas start to oscillate in phase and generate one giant packet of coherent laser emission. Let the dependence of the emission intensity on the pumping power be the same. The generation mode corresponds to the hypercritical cell production. The light field in a laser is generated by excited atoms. Furthermore, the field exerts an opposite effect upon the atoms: the stimulated emission arises being interfered with two factors: a permanent dissipation and fluctuations which perturb the emission process by their random action. For these reasons, the stimulated emission field in the subcritical regime is damped out. Above a certain pumping power value the amplitude begins to rise. As a rule, the dampening dies away for one mode, the amplitude of which acts as an order parameter.

Consider another example of self-organizing processes, i.e. a periodically excited pendulum. The equation of motion of the pendulum is written as (Mikhailov & Loskutov, 1996):

$$\frac{d^2\theta}{dt^2} + \gamma \frac{d\theta}{dt} + g \sin(\theta) = F_0 \cos(\omega_0 t),$$

where θ is a deviation angle, g is the gravitational acceleration, γ is a damping constant, ω_0 is the frequency of the external force with F_0 amplitude (the mass is taken equal to unit). A numerical solution of the equation is shown in Fig. 1.2.1. The time dependence of angle $\theta(t)$ becomes chaotic if the amplitude F of the force exceeds the threshold value F_c.

The next experimental physic-chemical system, in which the formation of spatial and temporal structures has been studied in detail, is the Belousov-Zhabotinsky's reaction (Haken, 2006). The organic molecules (e.g. the malonic acid molecules) are oxidized by bromate ions during the catalyzation of the oxidation-reduction system (Ce^{4+},Ce^{3+}). The reagents are $Cl_2(SO_4)_3$, $NaBrO_3$, $CH_2(COOH)_2$, H_2SO_4 being involved into 18 elementary reactions (Mikhailov & Loskutov, 1996).

The generalized equations for the reagent concentration $\{C_i\}$ in the system of chemical reactions have a form of a system of non-linear 1st-order differential equations (Babloyantz, 1986):

$$\frac{dF(X,\lambda)}{dX} = F(X,\lambda),$$

where $X = (C_1, C_2, \ldots, C_k)$, $F(X,\lambda)$ is a non-linear function $\{C_i\}$, λ is an external control parameter. The variable, which possesses a chaotic behavior in the Belousov-Zhabotinsky's reaction, is the Ce^{4+} ion concentration C measured by the selective light absorption by these ions. The average time spent by the substance in the flowing reactor (Fig. 1.2.1) is an external control parameter.

1.2.2. Self-organizing processes in information technology

Among all the natural objects the biological ones are functionally and morphologically the most complex and highly organized. During the protracted period of biological evolution functioning away from the equilibrium state, they permanently receive the energy and matter flux, and preserve the memory of the forms and functions attained within this period (Yurkovych, Seben & Mar'yan, 2017).

The important balance is reached between short- and long-range effects, controlled by the energetic situation. The system always tries to realize the lowest available energy (which is the cluster (in microscopic range) with a five-fold symmetry). On the macroscopic scale it is the ordered occupation of space, which eliminates the five-fold symmetries and therefore contradicts the microscopic requirements. This delicate balance leads to the dynamic vibrations, which can be easily frozen in by one of the forces dominating in the system. A protein, with its saturated, de-saturated states in the living process (balancing between the low-energy state at the microscopic level, which is the saturated molecule, and the low energy state required by the metabolism, which is a non-saturated state), also shows this basic dynamic construction and builds a system called life. The self-organizing builds up this dynamical equilibrium in all the organizing levels from the water-transfer through proteins and up to the organism as well. The dynamical vibration is effective for the whole living organism. It has an effect on every level of organization of the system: starting from the protein building up the total unity.

Accordingly, the system creates a balance between nutrients and end-products that breaks down the energy stored in the chemical bonds of nutrients and creates the end-products, in which the chemically stored energy is low. At the same time certain biological systems (plants) are capable of executing this process in reverse, for which they receive their energy from the solar energy and electromagnetic radiation. (This process is a fundamental conversion, which makes the nutrients available to the other life processes which are not capable of such a conversion).

The cell is the traditional object of biophysical research. Cellular biophysics processes as well as the processes of energy and information exchange typical of biological systems are also inherent in cells. The substantial non-homogeneities are also observed at the cellular level (Babloyantz, 1986).

Knowledge of the principal regularities of the formation of structures in the media open with respect to the energy and mass exchange allows one to turn to the purposive creation of distributed dynamical systems, which form one or other spatial structures. One of the principal applications in this case is the problems of digital processing of information. The use of spatial structures, not discrete signals, as the elementary unit of information processing, allows the computer efficiency in the artificial intellect tasks to be increased drastically. There is some evidence that just the similar mechanisms underlie the human brain functioning (Mar’yan & Szasz, 2000).

As it is known, the brain is a giant network of tens of billions nervous cells (neurons) bound by the branches (dendrites and axons). The number of bindings of a single neuron may reach tens of thousands. The mechanism of the action of a separate neuron is responsible for the fact that the nervous cell may be in one of three discrete states – rest, excited and refractive (the latter corresponds to the unexcited state). The interstate transitions are controlled both by intracellular processes and electric signals coming from the other neurons through the branches. The change from the rest state to the excited one occurs in a threshold manner at almost simultaneous reception of a great number of pulsed excitation signals. The neuron spends some time in the excited state and then transits independently to the refractive state. This state features quite a high excitation threshold: the neuron almost fails to respond to the excitation signals received. After a period of time the excitation ability is restored, and the neuron relaxes to the rest state.

Thus, common physical and chemical systems may possess a complex behavior with a series of peculiarities belonging to the living systems. A question arises naturally: whether one is able to explain some of these peculiarities by the transitions induced by non-equilibrium and relevant instability mechanisms (say chemical autocatalysis).

Besides the structure of a separate nervous cell, the global aspects of brain activity, i.e. the specialization of its large areas and functional communications between these areas, are also studied relatively well. At the same time little is known about the way of information processing at the intermediate level, inside the neuron network areas involving only tens of thousands of nervous cells. The brain is quite frequently compared with a computer. In addition, it is assumed that each excitation pulse carries the unit information, while neurons play a role of logical switches completely similar to the computer elements. However, in our opinion, the brain functioning is based on absolutely completely other principles. There is no rigid communication structure between the neurons in the brain similar to that in a computer. The reliability of separate brain elements (neurons) is considerably worse than that of the modern computer units. The damage of even those areas, which comprise quite a large amount of neurons, does not occasionally affect the efficiency of information processing in this area of a human brain. A part of neurons dies during the organism aging.

The computer network resembles the multicellular organism. After the program, i.e. the repertoire of reactions of each computer and the initial status of all of them, is being indicated, the network starts to live its own life and simulates the corresponding process. From that viewpoint one can assume that the brain stores and processes the information in images. It operates as a computer, in which the surrounding world is mapped in the spatial-temporal structures of neuron activities. An evocative simulation allows the future events and schedules of actions to be predicted. Such a mechanism of the brain operation was, probably, developed in the course of biological evolution. In animals, the basic function of the nervous system is to transform the senses prompted by the environment into a certain motional activity (Mikhailov & Loskutov, 1996).

A viewpoint that the human brain operation is based on the learning principles seems to have received recently much recognition. Consider, for instance, the possible sequence of steps expected to be performed for solving the problem of how to distinguish the triangle among all other polygons. The first step is to distinguish the lines and check whether their quite large areas are close to the straight-line sections. Then one has to choose vertices, i.e. the points where two lines cross. The next step is to create the intermediate concise image of pattern – its graph. This graph fixes only the existence of relations between the vertices independently of lengths and orientation of the lines, which realize these relations. Now, when each graph corresponds to the whole class, one has to recognize graphs, thus giving the final answer for the problem stated. Therefore, the possibility to solve this simple task requires the creation of semantic structures – graphs. Each graph, in turn, may also be considered as a certain notion (e.g., a triangle graph) and act as the elements involved in the semantic structure of the next hierarchic level. All the necessary operations with semantic structures are executed in the brain in the analog way similarly to certain dynamical processes in the complex distributed non-linear system. The brain is like the medium where semantic structures do evolve, interact and compete with each other.

The process of development of an alive organism does not require an interference of external controlling forces, and there is a sequence of the independent acts of self-organization. Handling of this process can be carried out with the help of inappreciable effects of controlling parameters. They influence the choice of this or that path of development at the moments, when the developing structure is able to bifurcate in the presence of several possible paths of evolution in information technology.

The education acts as a living organism, for which there are ways of functioning that provide a coherent and complete perception of information (Yurkovych, Seben & Mar'yan, 2017). With the help of synergetics, various aspects of operation of a human organism, in particular, in medicine are researched (Mar'yan & Szasz, 2000). At normal operation of almost all the systems of vital activity, the intermediate mode between the chaos and the order (the so-called determined chaos) is characteristic. Thus, for example, for the processes of respiration, palpitation and mental equilibrium the particular measure of the chaos necessary for maintaining the health of human being is peculiar. For example, the extreme modes of heart rate (arrhythmia and excessively ordered rhythms) are dangerous and testify to its illness. Too regularly fragile heart is not able flexibly to react to varying external conditions. The health is a particular balance between the chaos and the order. The concept of dynamical illness in recognition and treatment of illnesses, and also for warning illnesses will be utilized. The stabilization of the vital activity is reached through the instability, the stationary values of change.

How many chaos can bear a sciences education not to be ill, when are random oscillations normal, and when are they dangerous? These problems are considered with the help of synergetics and are studied in this book.

Synergetics and self-organization processes are some of the innovative approaches in the teaching of disciplines, in particular the physics, mathematics, computer modeling. This is especially significant at the present stage of the development of information technology (Chen & Lee, 2009), namely the dissemination and exchange of information using Internet, software development for mobile phones of Smartphone, Google services, which greatly expands the range of users and provides new opportunities for in-depth perception and radically new approaches in expulsion and interpretation of the laws of physics. In this context, presented the approach in the book is relevant and required.