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Universal arrow of time
and basic paradoxes of physics

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Statistical classical mechanics, quantum mechanics and gravity theory (quantum and non–quantum) are all developed and well–known theories. These theories represent the basis of modern physics. Statistical classical mechanics enables the derivation of properties of big bodies; it investigates the movements of the smallest atoms and molecules that constitute these bodies using Newton’s classical laws. Quantum mechanics defines the laws of movement of the smallest particles at small atomic distances and considers these particles as probability waves.

The laws of quantum mechanics are described by the Schrödinger equation. These laws of movement are very different from the laws of movement of large bodies, such as planets or stones.

Gravity theory describes the behaviour of massive bodies and the Universe. The described theories have been known and well studied for a long time. Nevertheless, they contain a number of paradoxes (Figure 1.1). These paradoxes force many scientists to doubt the internal consistency of these theories. However, the given paradoxes can be resolved within the framework of existing physics without introducing any new laws. These paradoxes that underlie thermodynamics, quantum mechanics and gravity theory (quantum and non–quantum) are discussed in this work. Approaches to solving these paradoxes are suggested.

The first approach relies on the influence of the external observer (environment), which disrupts the correlations in the system and results in the time arrow alignment. The second approach is based on the limits of the self–knowledge of the system for the case when both the external observer and environment are included in the considered system.

The concepts of Observable dynamics, Ideal dynamics and Unpredictable dynamics are introduced. The phenomenon of complex (living) systems is contemplated from the perspective of these dynam-
ics. Perspectives on the practical use of Unpredictable systems for artificial intelligence are considered.

Indeed, this book is realization of ideas of new cybernetics in physics for the solution of the basic paradoxes [1]. The key idea in cybernetics is feedback [2]. It is a closed cycle: the object affects itself through other objects. Within the scope of the new cybernetics [3–6], this idea has been developed further – the cyberneticians (investigators and observers) and cybernetics (the studied/observed system) influence each other and thus create feedback. The new cybernetics is otherwise known as the cybernetics of cybernetics, or second–order cybernetics. Heinz von Foerster attributes the origin of second–order cybernetics to the attempts of classical cyberneticians to construct a model of the mind [3]:

a brain is required to write a theory of a brain. From this follows that a theory of the brain, that has any aspirations for completeness, has to account for the writing of this theory. And even more fascinating, the writer of this theory has to account for her or himself. Translated into the domain of cybernetics; the cybernetician, by entering his own domain, has to account for his or her own activity. Cybernetics then becomes cybernetics of cybernetics, or second–order cybernetics.

A set of basic features of the new cybernetics associated with this idea can be formulated:

— “A new type of feedback” [3]: New type of feedback is the connection of the observed system to itself by means of the observer. The new type of feedback also serves as the connection of the observer to him–or herself by means of the observed system.
This connection is often small and can be neglected, but in many important cases, the connection cannot be ignored because of “the instability and chaotic nature” of many real systems, which are discussed below.
— “Mutual influence and correlation of the observer and the observed system” [3, 7]: The inspected (observed) system cannot be viewed in isolation from the inspector (observer). There are interactions and correlations between them that often must be accounted for, in spite of their apparent smallness, because of
“the instability and chaotic nature” of many real systems, which are discussed below.

— “Relativity of the observers” [7, 8]: Different observers can see the observed system in different ways, but this does not lead to a contradiction.

— “Impossibility of complete self-description” [7]: The system cannot fully describe and predict (understand) itself. In fact, an attempt to perform a complete self-description of the system leads us to a contradiction. For example, we use ink to describe the system. However, this ink is also included in the system during the self-description process. That is, this ink also must be described. This can be performed with the use of different ink, but then this new ink also must be described. This process can be continued ad infinitum. However, an incomplete (partial) self-description is possible.

— “Complexity” [9]: Real systems consist of a large number of parts that interact with each other and the environment.

— “Instability and chaotic nature” [10]: Many real systems are extremely sensitive to weak external interaction. This weakness leads to the importance of even the smallest interaction of the observer with the observed system.

— “Principal emergence” [11]: The whole often acquires new properties that cannot be predicted on the basis of even a complete knowledge of its parts and the interactions among them. Indeed, we know that the observed system interacts with the observer. This interaction leads to the fact that the observed system be open and exposed to unpredictable external noise. Consequently, the complete system must include the observer. However, if the observer is included in the system, the latter becomes unpredictable because of “the impossibility of complete self-description”.

— “Integrity and relationship (correlation and interaction)” [7, 11–13]: Our world is not a collection of random bodies and events but rather a holistic set of cooperating (albeit sometimes very weak) objects that correlate with each other. That is, our world is more like an interconnected organism than a complex of random events (a holographic model of the universe or a holographic model of the brain, for example).
— “Principal unpredictability of science (uncertainty)” [7, 11]: Many systems cannot be described in detail by using purely logical, scientific methods, such as mathematical modelling. Many systems, though, are unpredictable but feature probabilistic laws. Here, we discuss stronger unpredictability, which is not featured even by probability theory. Often, this impossibility of prediction is principal and not associated with the complexity of the system. This interaction leads to the fact that the observed system be open and exposed to unpredictable external noise. Consequently, the complete system must include the observer. However, if the observer is included in the system, the latter becomes unpredictable because of “the impossibility of complete self–description”.

— “Principal parameters of the system” [7, 14]: A “complex system” often involves many parameters that describe it. However, in many cases, the dynamics of the system and its interface can be accurately described using only a small number of parameters. These are called the principal parameters of the system. The principal parameters constitute one of the methods of overcoming “the complexity” and “unpredictability” of the system. Examples of such principal parameters are the thermodynamic variables in physics and “features”, which are the characteristics of multi–pixel objects used in the theory of pattern recognition.

— “Intuition (insight)” [7, 15]: In psychology, intuition occurs when a solution is reached very quickly and suddenly. What cannot be achieved by scientific methods can be achieved by means of intuition. By definition, intuition does not derive from science. Intuition is a method of overcoming the scientific “unpredictability” of the system “in practice”. In fact, the observer interacts with the outside world, is correlated with it, and acts as a part of it. This allows him or her to simply act on intuition (from some unexplained internal motivation) to achieve goals that cannot, in principle, be achieved by means of purely scientific methods.

— “Interdisciplinary approach” [16]: Very similar properties and phenomena occur in systems that belong to completely different areas of knowledge.

The main features of the new cybernetics can be illustrated with the help of examples from various areas of knowledge.
Mathematics and logic

In mathematics, feedback is common and leads to the proof of the most fundamental theorems of impossibility. Here are some examples:

— Gödel’s incompleteness theorem [17, 18]: Gödel introduced a single-correspondence function between a set of characters and the integers. This allowed him to formulate assertions about the properties of the axioms of a formal mathematical system as theorems regarding the arithmetic of integers. He could thus make a clear statement *I am lying*, which refers to itself (“feedback”). Such a statement is mutually contradictory and can be neither true nor false. Thus, it can neither be proved nor disproved if the system of axioms is consistent. This leads to Gödel’s incompleteness theorem: every self-consistent formal system of axioms, including the arithmetic, is principally incomplete.

— Gödel–Turing theorem: One can prove the impossibility of an algorithm that can be determined in a finite time whether a different algorithm will work indefinitely [19], based on the given input parameters, or will stop. An attempt to apply this algorithm to the input of itself (“feedback”) will lead to an inevitable contradiction, which proves its impossibility.

— Set theory [20]: Let us define the set of all sets that do not include themselves as subsets. Will such a set include itself (“feedback”)? Trying to answer this question inevitably leads to a contradiction. This means that, for the purpose of the consistency of the theory of sets, it is necessary to impose restrictions on the ability of certain aggregates to be sets.

The neural theory of mind

To illustrate the principles of the new cybernetics and the proofs of the impossibility theorems, let us present a few examples of the neural theory of mind:

— “Is it possible to create an electronic mind that completely copies the work of neurons in the human brain and is equal
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to the human mind in terms of strength?" [7, 21–23] The answer to this question is as follows: not completely. Indeed, the work of neurons is determined by the internal state of the neurons, which, in its entirety, is equivalent to the full range of its constituent atoms. Next, the work of brain neurons depends on not only the neurons themselves but also the surrounding cells (glial cells). These cells depend on the operation of the whole organism. At the same time, the operation of the whole organism depends on the environment. That is, to simulate the brain in its entirety, it is necessary to simulate the entire world around it in its entirety to an approximation of atoms. This, in principle, cannot be done because of “the impossibility of complete self-description” [7]. Of course, this does not mean that the operation of the mind cannot be modelled. In a certain approach, the operation of the mind can be modelled by introducing “the principal parameters” that describe neurons. However, it is highly unlikely that it can be done in its entirety, including the most subtle intuition. A little joke serves as an example. An apple fell on Newton’s head, which led to the brilliant discovery of the law of gravity. Therefore, to create an electronic mind that can replicate this finding, we must simulate not only the mind of Newton but also the whole world around us, which led to the fall of that apple on his head at that very precise moment (“a new type of feedback” between the observer and the observed system)!

— “Is it possible to create a man and his brain that completely copies someone else’s?” [21] No, it is not. The answer and its reasoning are the same as in the previous paragraph. Indeed, there is no principal difference between exact physical copying and copying onto an electronic medium.

— “Is it possible to create a code of the brain that establishes single correspondence between the thoughts and the work of the neurons? In addition, is it possible to create a device that is thus capable of reading minds?” [7, 21, 22] In spite of the fact that modern science says that consciousness (or at least its observable manifestations) is completely determined by physical processes, the answer is the same: not completely. This is easily illustrated by “feedback” [21]. Let us suppose that such a device is created
and that it can read a person’s thoughts (for example, define his or her anger). Moreover, imbued with full confidence in the device, the person can use it to judge his or her condition. However, what does the device show if it is used by the person to understand him– or herself? What happens? New feedback mechanisms of the brain appear, and a new “code of the brain” is formed, which includes not only neurons but also the mind–reading device. Moreover, such feedback can occur naturally. For example, a person may assess his or her wrath from the sweat on his or her forehead or the fright of nearby people. They play the role of the mind–reading device. Thus, the code of the brain in its entirety depends on not only neurons but also other cells of the body and even the environment. Furthermore, it can change dynamically over time. This does not mean that the “code of the brain” is completely inscrutable. The “principal parameters” of neurons can describe it. However, there are natural limits to the completeness of such a description, which are specified above.

**Computer science**

— “Is it possible to create a Chinese Room in reality, at least in principle?” [7, 21, 22] Not in its entirety. Just as we have shown above, the full set of rules for the human person in the Chinese Room is equal to the size of the universe and must include that person, which cannot happen because “the impossibility of complete self–description”.

— “Can a computer behave unpredictably [7]?” Yes, it can. An example is the quantum computer (or its classical counterpart: an unstable analogue computer [24–27], Appendix B.10, Figure 3.5). Indeed, the work of such a computer can only be assessed by the person who initiated it. Any outsider who was not present at its start–up will only violate its operation when trying to understand how it works. Such a system is unpredictable for him.

— “Can an intellect that is comparable to that of a human being work only on the basis of scientific logic and not possess in-
tuition?” [7, 28] No. We have said above that the presence of “unpredictable” systems limits the scope of purely scientific knowledge of the world.

— “Can a computer possess intuition and guess better than the genetic algorithm?” [7, 28] Yes. To model intuition, computers often use a random number generator. However, such a model is primitive [29]. For a more accurate modelling of intuition, it is necessary to allow the environment to influence this generator. Then, correlations appear between the environment and the generator. Introducing such correlations may allow the computer to better “guess” the properties of the environment than a simple random generator does in the genetic algorithm. It should be noted that this intuition bears a high price: the computer itself becomes an unpredictable system, which can lead, for example, to a robot revolution.

— “Can the intuition of an artificial intelligence be fully equivalent to that of a human being in terms of efficiency?” [7] If humans were able to clearly formalise their goals and desires, the answer would be yes. However, many desires of people cannot be formalised and are not clear even to them. As we have written above, it is impossible in principle to simulate the human in its entirety. Therefore, a perfect machine intuition cannot be created either. Only human beings themselves know best what they need.

— “Is it possible to create an artificial intelligence that is equivalent to that of men in terms of efficiency?” [4, 7] No. Because human intuition cannot be copied in its entirety, this means that human beings will always perform certain tasks better than the machine can because they possess a better understanding of their desires. Moreover, a possible uprising of robots is the best example of such an inadequacy of the artificial intelligence because it is unable to solve the problems that require solution for the person as such a person or better.

— “How is it possible to create an artificial intelligence comparable in strength to a human for the solution of formalisable problems (problems with a precise description and a precise purpose)?” It seems that such an intelligent system should be created similarly to the evolution and education of a human
person but at a more accelerated rate. It should be a training
and self–learning system. Most likely, the most suitable model
will be similar to a neural network. Even existing heuristic algo-
rithms should be transformed into neural networks. The
intelligent system should be created from simple forms into
complex forms: it is necessary to begin from imitating the be-
haviour of the simplest insects, which have the most primitive
nervous systems. Then, it will be necessary to complicate the
task gradually, creating more and more complex robots, using
previous results for subsequent stages. It will be necessary to
use something like natural selection. This is the genetic algo-
rithm. If we wish to model intuition (for the creation of such
an intelligent system or for the solution of non–formalisable
problems), it will be necessary to use a generator of random
numbers that is correlated with the investigated environment.

Economic, political, psychological, and sociological sciences

Here, the importance of the above principles is evident \[30\]. The in-
fluence of the observer on the observed system is very large. Any
“theory” that captures the minds of many becomes a part of the in-
spected system itself. For example, the winning theory in the stock
market is impossible; if it were true, all would have to win, but that is
impossible. Therefore, these sciences cannot be completely consid-
ered to be science. Intuition has always played a huge role here, a role
that is much more significant than in other sciences.

Physics

Physics would seem to be the most exact science, in which the impact
of the observer is immaterial, as opposed to the economic, political,
psychological, and sociological sciences \[30\]. How can the observer
influence the results of experiments with elementary particles in an
accelerator? However, for many real physical systems, the observer
does indeed influence the system; these systems possess the properties
of instability and chaotic nature. This leads to the resolution of many
paradoxes in physics. The remainder of this work is dedicated to such situations in physics. We will give only one example here.

“Why is the beginning of the universe characterised by low entropy? Why cannot our universe be the result of a gigantic fluctuation from the thermodynamic equilibrium with maximum entropy?” The answer is simple: in fact, it can be. Moreover, this is more likely under the laws of statistical physics. However, experimentally determining which of the above two theories of the origin of the world is true is impossible in principle because of “the impossibility of complete self-description” and self-observation. Feynman [31] argues that in the case of a giant fluctuation uprising, there would have to be an “ocean” of thermodynamic equilibrium around us, and he sees a contradiction here. However, there is none. The observer may simply be unable to observe this “ocean”. After all, he is a part of this fluctuation and interacts with this world. He cannot break out of its limits, as his uncomfortable environmental equilibrium will be destroyed just by his trying to observe the surrounding “ocean”. Thus, the low-entropy theory of the initial universe is simply a convenient point of view rather than an established scientific fact. We can see only a small part of the observable universe, and yet, we try to assess the entirety of the universe on the basis of nothing but a small part of it, which is a very error-prone approach.

To make the work clear for the inexperienced reader, we include some necessary basic concepts of statistical physics and quantum mechanics without the use of formulae. The necessary exact formulae and their explanations can be found in the Appendices. For a better understanding of the text, it is supplemented with illustrations.

At the very beginning of this work, it is necessary to make a number of extremely important notes.

a) This work is not a philosophical work on physics, unlike some of the other works on the paradoxes of quantum mechanics. We use scientific methods to consider a solution to these paradoxes. We also construct the physics that excludes these paradoxes and determine the requirements that make such physics possible. The misunderstanding of physics that leads to these paradoxes produces a set of physical, but not philosophical, errors.

b) This work is not an attempt to provide a new interpretation of quantum mechanics. All of the interpretations (e.g., the multi-
world interpretation and Copenhagen) merely try to provide a more or less evident explanation of quantum mechanics. These interpretations do not solve any of the paradoxes and do not introduce anything new to the physics. The author considers all of the existing reasonable interpretations to be admissible. The paradoxes’ solution in this work is not related to any interpretation and is based on general physics.

c) This work is not a popular scientific work and includes new, original ideas. The work is tailored to a very wide set of specialists, including biologists, physicists (in quantum mechanics, statistical physics, gravity, thermodynamics and non-linear dynamics) and computer-science specialists. Therefore, we provide a general review of the basics of physics. Although this review can seem trivial to one expert, it will nevertheless be very useful to another expert. Moreover, there are no formulae, only figures and text. All of the formulae are contained in the Appendices. The author is not a pioneer of this style. Examples of similarly styled works include Penrose [32, 33], Hofstadter [29], Mensky [28, 34] and Licata [11]. These works are not popular works despite their “easy” style. The author hopes that he will also be allowed to use this useful style.

d) This work is not only a review of works that have already been completed (although many references are given); it also includes the original ideas of the author.

e) The author does not attempt to find any new laws of physics; we respect Occam’s razor. All of this review lies within the framework of already existing physics. The motivation to write this work was the fact (paradox!) that the author has not encountered any work or physics textbook that provide a full and clear explanation of these physics paradoxes and their consequences. Moreover, these paradoxes are ignored in many works, while, in other works, the explanation is not complete or not correct. In many works, the solution is based on only one interpretation of physics (typically multi–world). Sometimes, some new (but not necessary!) laws of physics are used for the explanation.

1. Mensky [34] and Peierls [35] assume that the quantum mechanics measurement paradox can be resolved by a change in the quantum physics laws and by the introduction
Why low–entropy initial conditions of the Universe are not enough to explain the entropy increase in the Universe? First, this explanation is correct, but not appropriate because of Occam’s razor: indeed, additional constrains on an initial condition can be introduced only if any different explanation from the known physical laws does not exist. But we demonstrate in this book that the entropy increase is a natural consequence of Hamilton dynamics. The second reason is following: Poincaré returns must result in the entropy decrease and time arrow reverse. Of course, this return time (of the Universe and its big subsystems) is much larger than life–time of the Universe. But for small subsystem return time is smaller than life–time of the Universe. During the Universe evolution, larger and larger systems can return. Therefore (in contradiction to experiments), it seems that we must observe increasing fluctuation of the Universe during the Universe evolution. Low–entropy initial conditions of the Universe cannot explain absence of such fluctuations. But “time arrows synchronization” can explain.

Who has priority in the discovery of the basic ideas about “time arrows synchronization” and “observer memory erasing”? As the author know the “time arrows synchronization” was previously considered by Thomson in (1874) [40] and developed by Zeh [41–43] and Kupervasser [44–46]. The “observer memory erasing” was considered in classical mechanics by Kupervasser [44–46] and in quantum mechanics by Vaidman [47]. Maccone [48] was the fist who published this idea in the popular per–review journal without any references to the relevant previous works. He was also impossible to give rele-

of the concept of “consciousness” in physics. Penrose [32, 33] and Leggett [36] assume that the laws of quantum mechanics are broken for sufficiently large macroscopic systems. However, many other physics problems have already been successfully solved without the introduction of new laws, such as the Gibbs paradox [37] and the interpretation of spin as the rotation moment of the Dirac electron wave function [38]. The broken symmetries of life or the Universe (such as the symmetry of time direction or the symmetry of right and left) can be explained with the help of the fundamental weak interaction. The weak interaction breaks these symmetries. A full explanation can be found in the Elitzur paper [39]. However, in the current paper, we neglect these small effects and search for some other reasons for the asymmetry of time.
vant replay [49] to the objections [50, 51]. Such reply was done by Kupervassar in this book (Section 3.2.5 and Application B.3.2) and in [50, 52].
Chapter I

Principal paradoxes of classical statistical physics

Figure 1.1

This part is described numerically in Appendix A.

1.1. Formulation of the basic concepts of classical statistical physics and principal paradoxes

1.1.1. Macroscopic and microscopic parameters of physical systems

This part is based on works [53, 54]. Let us begin our discussion of statistical physics. We will look at the gas outflow from a jet engine nozzle (Figure 1.2).

We can see a distribution of density and velocity for flowing gas but only for large volumes. These volumes include an enormous
number of invisible molecules. The easily observable density and velocity distribution of flowing gas are defined as the macroscopic parameters of the system and provide an incomplete description of the system. The full set of parameters is given by the velocities and positions of all of the gas molecules. These parameters are defined as the microscopic parameters. A flowing gas is defined as an observable system. The system is termed isolated if it does not interact with its environment. The internal energy of the system is the sum of all of its molecules’ energies. From now on (unless otherwise stated), we will consider isolated systems with a defined internal energy and finite volume.