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PATH OF MODERN NATURAL SCIENCES: FROM DISCOVERY OF REALITIES TO STUDY OF THEIR ATTRIBUTES

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Abstract. We analyze the development of the natural sciences according to the scheme: "… reality – attributes – reality – attributes". Any material reality is interpreted as a carrier of attributes manifested in a certain range of its experimental study and at a certain theoretical level of data understanding. More sophisticated experiments and refined theories lead to a more detailed and correct vision of realities and their attributes. The latter initiates new experiments and creation of new theories. These cognitive processes lead to the discovery of new material realities with their additional or refined attributes compared to those previously known. The objectivity and relative truth of scientific statements about the realities under study and their attributes are based on a qualitative or quantitative correspondence between theoretically calculated values of attributes and their experimentally measured values. We emphasize that the isolation and adequate historical and philosophical analysis of those cycles requires professional knowledge of the analyzed complex scientific material and cannot be implemented within the framework of oversimplified ideas about science and the role, which theories play in it. Examples of such ideas are the understanding of theories solely in terms of their refutation and confirmation or even the replacement of theories with fuzzy sociological concepts such as a paradigm and sociocultural determination of the scientific results. Those views often become the source of idealistic, irrational, and postmodernist interpretations of science and its history.

Key words*:* Material realities and their attributes, attributes and their values, experiments, theories, qualitative and quantitative correspondence between calculated and measured values of attributes.

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ШЛЯХ СУЧАСНИХ ПРИРОДНИЧИХ НАУК: ВІД ВІДКРИТТЯ РЕАЛІЙ ДО ВИВЧЕННЯ ЇХ АТРИБУТІВ

Анотація. Розвиток природничих наук аналізується за схемою: «… реальність – атрибути – реальність – атрибути …». Будь-яка матеріальна реальність інтерпретується як носій атрибутів, що проявляються в певному діапазоні її експериментального вивчення та на певному теоретичному рівні розуміння отриманих даних. Більш складні і продумані експерименти та більш витончені теорії ведуть до більш детального та повного бачення реалій та їхніх атрибутів, що ініціює нові експерименти та створення нових теорій. Ці когнітивні процеси ведуть до відкриття нових матеріальних реалій із додатковими або вдосконаленими порівняно з раніше відомими атрибутами. Об'єктивність і відносна істинність наукових тверджень про досліджувані реалії та їхні атрибути засновані на якісній та кількісній відповідності теоретично розрахованих значень атрибутів їхнім експериментально виміряним значенням. Підкреслюється, що їх виокремлення та адекватний історико-філософський аналіз потребує фахового знання складного наукового матеріалу й не може ефективно здійснюватися в рамках надмірно спрощених уявлень про науку та роль, яку в ній відіграють теорії. Прикладами таких ідей є розуміння теорій виключно з позиції їх спростування та підтвердження або навіть заміна теорій нечіткими соціологічними концепціями, такими як парадигма та соціокультурна детермінація наукових результатів. Ці погляди часто стають джерелом ідеалістичних, ірраціональних та постмодерністських тлумачень науки та її історії.

***Ключові слова**:* матеріальні реалії та їх атрибути, атрибути та їх значення, експерименти, теорії, якісна та кількісна відповідність розрахованих і виміряних значень атрибутів.

The devil is in the details of scientific theories

Introduction. Natural sciences study differentiation forms of nature: from hadrons and quarks to galaxies and the Universe, from prokaryotes to mammals, from chemical elements to complex compounds. All of them do not depend on the artefacts produced by the mankind and on the human beings *per se*. Sciences study natural objects by direct observation and experimental investigation as well as theoretical analysis of their attributes (properties, relationships, manifestations, processes, states, etc.). Spin of elementary particles and Hubble expansion of the Universe can be considered as examples. In a sense, the understanding of properties depends on experimental and theoretical means. Scientists use available means and construct new ones based on already acquired knowledge. Obtained with the help of modern experimental equipment, new data and their theoretical explanation create a more complete and accurate vision of realities and their attributes. The continuously refined knowledge is the basis for creating new one. In this connection, at least three cognitive moments arise: (1) confidence in the previous scientific results, (2) awareness of the complexity of realities studied, and (3) the transition of science from the discovery of realities to the analysis of their attributes. These historical and philosophical issues and their interrelation are the subjects examined in this article.

Confidence in science. Because scientists deal with material realities and their attributes, they are not free in their activities but should follow certain rules elaborated by their predecessors during several hundreds of years. Thus, objectivity is the benchmark for scientists, one of the pillars, on which the whole building of science is based. That is why the confidence in scientific studies of respected colleagues unites scientific communities into one entity. Of course, the results of investigations can be checked and clarified to continue the progress of any carefully chosen scientific area under study.

Despite existing (although not very numerous) falsifiers [43] and "sincere" incompetent scholars, the current self-consistent scientific system very swiftly rejects antiscientific views making the progress continuous and invincible. Being part of the community, let us turn to some aspects of the scientific vision of the world, which we consider proved, justified, and interdependent.

"Meanwhile, the development of true science is consistently reducing the space for fantasies about future discoveries. Any innovative ideas and discoveries must fit firmly into the framework formed by already accumulated, reliably established relationships, facts, and values. As science develops, its framework grows with new connections and becomes increasingly rigid … Therefore, when it comes to such fundamental concepts as new fields and forces; physics imposes strict restrictions on their possible values and scope" [3]. To understand those issues, it is necessary to use not only general ideas about science, but also the detailed pattern of it as a complex system to obtain new knowledge.

Ontic principles of modern science. We start with reviewing of some basic modern scientific ideas about nature and forms of its differentiation [52].

First, nature is a hierarchical system of various coexisting and interacting material realities (forms) that do not depend on whether they are studied by any human beings [18]. In other words, in full accordance with *Einstein*'s point of view, the Moon exists regardless of whether we look at it or not. Modern quantum mechanics does not refute this statement, although any probe (a certain auxiliary material reality used in the experimental research) interacts with an object, including a microscopic one. In the latter case, this interaction significantly affects the movement of a microscopic particle, that is, it changes the quantitative value of one of its attributes. Nevertheless, statements about matter as a representation of our measurements and observations make up the old false subjective idealism [19].

Second, there is no reason to appeal to supernatural (immaterial) factors, entities and beings when describing, explaining, and studying natural material objects. Opposite statements about instantaneous or repeated spontaneous acts of creation conducted by a supernatural demiurge, who controls them "from the outside", are manifestations of objective idealism. Our criticism of idealistic views has nothing to do with fashion or our arbitrary optional choice of a worldview position but is the result of human scientific practice lasting for thousands of years and being the common heritage of both "ordinary people" and brilliant scientists.

Third, after the so-called Planckian period of the Universe evolution, all the formations concerned are emergent, that is, they arise at a certain stage of the evolution [36]. Moreover, the formation at earlier stages creates the conditions necessary to the emergence of subsequent stages. These issues are studied by cosmology with cosmogony, stellar astrophysics, and planetology. The detailed description and explanation of the reasons and nature of the Universe structuring are extremely important for the analysis of past and future terrestrial life, including the fate of the mankind, and in connection with the anthropic principle [10].

Fourth, science will never supply answers to *all meaningful* questions of the construction of the Universe and its formations. However, with the development of science, the scope of questions, to which it will be able to provide reasonable answers, will grow and these answers will become practically more significant.

Most often, in the minds of scientists and philosophers of science, a spatial complex vision of natural formations (forms of the matter self-differentiation) prevails. We call them natural realities or, shortly, *realities*. According to this vision, realities may be characterized by a relatively independent existence, have certain fixed or not rapidly changing spatial coordinates and keep their identity over a certain period. This vision is useful for the first meaningful visual description of the material world structure. In this case the space is treated as a simple container for matter, which is inherent to the traditional Newtonian physics. Newton himself, because of deep reflections clearly understood the approximate character of such a vision. However, but bearing in mind the immature level of science at his time he had no other choice than to accept this frame to build a firm basis for specific calculations for practical purposes. Later, the absolute space and time were replaced by more complex constructions of *Albert Einstein* special and general theories of relativity [13; 40], stimulated by *Ernst Mach* philosophical criticisms [47]. Trying to preserve the clarity of the further speculations, we shall limit ourselves to the classical view of space, keeping in mind the approximate character and fundamental flaws of such an approach.

Anyway, if one takes spatial dimensions of the modern science, they range at least from 10^{-13} cm to 10^{28} cm. Physicists with the help of the large collider at CERN and other less celebrated accelerators of elementary particles are studying the smallest of the realities known to exist – quarks and gluons –. The largest reality available to humankind – the observable Universe – is studied by cosmologists armed with modern terrestrial and space telescopes such as telescopes *Hubble*, *Planck*, *Chandra*, *Spitzer*, *Kepler*, and *Webb* [49]. Physics, in principle, does not rule out the existence of realities both spatially smaller than quarks and larger than the observed Universe. Nevertheless, currently, the existence of such exotic cases stays unproved.

Figure 1 shows a scale of spatial dimensions and typical realities characterizing its sections. Hypothetical exotic realities and their corresponding spatial scales are showed in gray. We shall focus on more specific, common to most natural sciences, forms of realities inherent in these science domains. Meaningful and formally mathematical modeling within the existing physical theories of such forms supplies an opportunity to construct reliable and accessible tests of knowledge about the relevant realities.

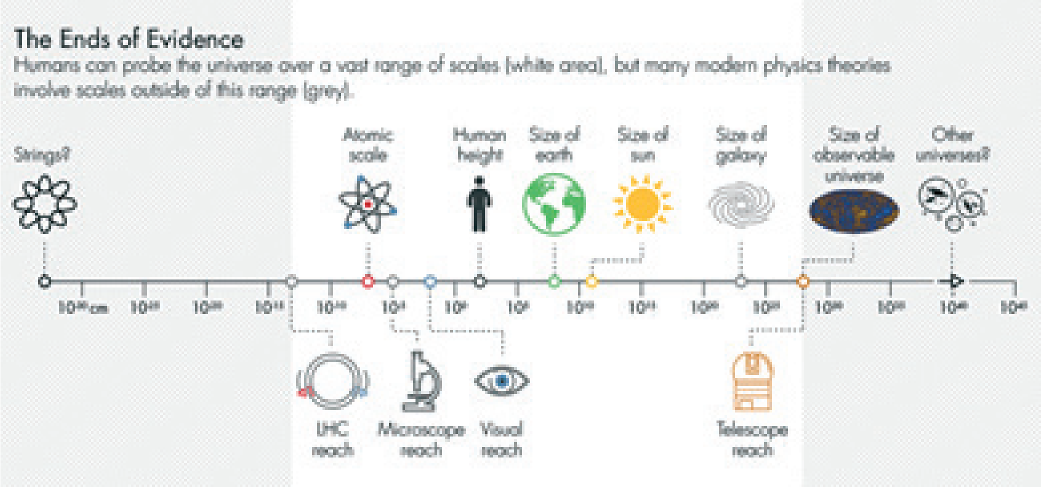

Fig. 1. The scale of the modern vision of nature and pictograms of realities typical for its different spatial scales [54]

Note that when studying almost all these realities their relatively independent existence is assumed, at least in the first approximation. For example, according to modern physics, quarks as components of hadrons cannot be observed outside hadrons. However, while studying the quark properties they are modeled as realities, which are independent from each other. Moreover, these realities are continuously transformed into each other, remaining quarks. This is like the activities of the three-faced Hindu god Brahma-Vishnu-Shiva. Each of its faces manages its specific function. Namely, Brahma causes creation, Vishnu – support, while Shiva destroys the world. The authors are sincerely grateful to Doctor of Philosophical Sciences *Yury Zavhorodnyi*, who drew their attention to this analogy with the Hindu pantheon.

Complexity of realities under scientific study. The figure shown above represents realities studied by natural scientists emphasizing the importance of quantitative values of their spatial dimensions. However, this information is only the first step in obtaining scientific knowledge about realities, the existence of which, according to modern materialistic views, is undeniable.

In natural sciences, to explain and describe their realities, the investigators usually appeal to their "hidden", i. e., sensibly inaccessible attributes and connections between them. Naturalists are lucky because the natural realities can be more easily studied than, e.g., human personalities.

To emphasize the specificity of natural realities, we shall use the name "attributes" to characterize their properties. Note that in physics, the name "physical quantity" is traditionally used to denote certain attributes. However, this name is not usually applied to such attributes of realities as their composition, state, and structure. In this sense, the name "attribute" is more general than "physical quantity".

The public associates the scientific progress with the discovery of previously unknown realities and related processes and phenomena. For instance, we can indicate the most distant galaxies, new elementary particles like the Higgs boson, genes that are "responsible" for certain defects and advantages of organisms, non-ordinary meta-materials, phenomena that are considered paradoxical from the conventional (which is sometimes inaccurately called classical) viewpoint, such as superfluidity and superconductivity or (superconducting or magnetic) levitation. Moreover, now, due to the high level of scientific development, not the realities themselves are directly measured, but some of their indirect manifestations in artificially created experimental conditions, as happens, for example, in particle colliders. Just as paleontologists use fossil bones to find the type of dinosaur and its way of life, physicists, relying on specific theoretical models, reconstruct the attributes of new elementary particles based on screens of measuring devices (and even more often, looking at the computer display). Only after many checks and theoretical processing of the results, scientists, who conduct the research, conclude that the obtained data correspond to certain realities with certain values of their attributes. We note that now significant discoveries are made mostly not by chance. On the contrary, they are stimulated by existing scientific theories as completely expected predictions.

Of course, the path to setting up modern ideas about currently known scientific realities was not direct and easy. After the discovery of particular objects and phenomena, having different spatio-temporal scales, a huge set of tasks arises consisting in a more accurate and detailed studies of general, special, and individual attributes inherent in these realities. For example, the phenomenon of superconductivity was discovered more than a century ago, but even now, it is under investigation by experimental and theoretical means achieving remarkable success in fundamental science and applications [23].

Indeed, one of the main advantages of modern science is that the intellectual and instrumental equipment of scientists is much more powerful than before. Modern natural scientists have already created well founded and experimentally confirmed scientific theories, which have been successfully tested and are still fresh enough to study other relevant realities. The principles of those theories are beyond any doubt, although their specific applications require large efforts. To overcome inevitable difficulties, scientists need a powerful research arsenal such precise and sophisticated devices as electron microscopes, femtosecond lasers and magnetic spectrometers.

But just like the discovery of America by Europeans, which was only the first step in the study of its anthropology, fauna, flora and geology, the discovery of indicated above realities by science is only the beginning of their research. Indeed, whatever the specific reality is, its further scientific cognition consists in finding as many of its attributes and their values as is needed. Such research gradually transforms reality from a *thing in itself*, about which merely the fact of its existence is proven, into a *thing for us,* about which scientists have a large amount of knowledge (but, of course, not a complete one!). Therefore, reality, as a carrier of certain attributes revealed in certain conditions, becomes a well-defined entity, because it is characterized from different sides. At the same time, it may turn out that some attributes inherent in this reality allegedly contradict others, being equally reliable. This is obviously a consequence of the incompleteness of the World picture, accepted by researchers while evaluating the set of attributes of the investigated reality. The electromagnetic radiation, existing in its wave and quantum incarnations, is a good example of such incompleteness, possibly being irreducible [28].

In the philosophy of science, attention is most often paid to the fact that attributes serve both to identify realities, that is, to unite them into one class, and to distinguish them, that is, to include them in different classes. In addition, one of the typical issues that philosophers have been actively discussing for centuries is the question of whether attributes exist independently of the realities that are their carriers. Some philosophers, bearing in mind the fact that the isolation and study of certain attributes requires a greater degree of abstraction than the isolation of the corresponding realities, believe that the attributes are something like either Platonic eternal and supernatural ideas that exist outside the material world of realities or imaginary constructions in the minds of scientists. Referring the reader to continuous discussions [4; 7; 12; 35], we shall below support and explain the following opinion: an attribute that is defined in relation to a certain (basic) reality as its integral feature is a reality itself only under certain conditions. Namely, the latter are such that it makes sense to consider this reality (attribute) as an object that exists independently of the basic reality.

In our view, the answer to the question of whether it is possible for a certain attribute to exist separately depends fundamentally both on it itself and on its basic reality. However, the standard situation in the natural sciences is that an attribute is a property rather than a material object, and thus does not exist separately from the object, like the Cheshire cat smile. If one turns to physical examples, then from a modern viewpoint, an electric charge is an attribute that does not exist separately from its elementary carrier, say, an electron or a quark. On the other hand, in condensed systems, where the individuality of separate atoms, molecules, and electrons becomes conditional, and various kinds of quasiparticles come to the fore, the charge becomes an attribute of some quasiparticles, which are the excitations of the condensed system, ripples against the background of the raging pool of strongly interacting primary micro-objects [51]. In this case, the "charge" attribute may even become non-integer (note that *real* non-integrity is inherent in quark charges), as, for example, is observed in the fractional *Hall* effect, where fractional charge of $e/3$ (e denotes the electron charge) is detected [26]. Of course, there is no collapse of the foundations, because it is precisely the charge of a quasiparticle that is observed, being the result of the collective interaction between many primeval micro-particles (in fact, good old electrons). However, the prefix "quasi" by no means says that the quasiparticle is a kind of an imperfect object. It is a completely material entity, and its existence is confirmed by experiment.

At the same time, one should consider the *presence* of a nucleus rather than a nucleus itself as an attribute of an atom. Simultaneously, the nucleus is a necessary component of the atomic structure. On the other hand, the study of the nuclei properties in the realm of high-energy probing particles should be interpreted as the investigation of a separate physical reality with its inherent attributes, e. g., a positive electric charge and a number of nucleons.

An "always relevant" scientific problem (along with the issue of the independent existence attributes) is also the issue of theoretical and/or experimental determination of quantitative values characterizing isolated attributes. In particular, the classification of realities described by the corresponding attributes depends on these quantitative values. Finding attributes and setting up connections between them is an essential part of knowledge about realities leading to a proper understanding of their nature. Thus, scientists become able to explain and predict their behavior under different initial, boundary, and external conditions. For example, in Aristotelian physics, the inherent desire to find a certain natural place was considered an attribute of sensory realities. For "heavy" realities such as stones, the Earth was considered such a natural center of gravity, and for "light" ones, such as flame or steam, the Sky played the same role. Those speculations "explained" why the former objects fall to stop on the Earth's surface and the latter fly up to the (in those times) inadvertently empty Heavens [6].

Attributes of realities studied by classical mechanics are their kinematic spatio-temporal localizations and trajectories, as well as dynamic characteristics (mass, energy, momentum, torque, angular momentum). The main task of mechanics is to find permanent relationships between those attributes and find quantitative values for each reality from the domain of classical mechanics. In fact, "eternal" dynamic closed flat trajectories of two bodies interacting according to Newton's law constitute a rare special case. The real trajectories of planets, comets or stars deviate under the influence of small perturbations-fluctuations and are unstable, so that the nowadays classical mechanics has a somewhat different character than the great French astronomer *Pierre Laplace* considered [8; 22; 34; 56].

In an ideal (unfortunately, unattainable) case, it would make it possible, knowing some quantitative values of attributes at a certain temporal moment, to calculate and empirically verify the calculated values at any other moment in the past or future. Moreover, the accuracy of measuring certain parameter values, e. g., the position of the Moon, in the seventies of the last century was about 40 cm and decreased now to millimeters [5].

In classical mechanics, one of the simplest theoretical systems, capable to describe the relationships between the attributes of macroscopic macro-body motion, is *Newton's* celestial mechanics with its three explicitly formulated laws and other assumptions, which the great English scientist never forgot about [42] and which authors of high school or university textbooks often do not consider. However, in the next, more advanced, versions of classical mechanics, which are more suitable to treat the behavior of complex mechanical systems, other schemes are used, e. g., *Lagrange* equations of the first or second kind. Such approaches, being conceptually equivalent, nevertheless introduce new concepts into mechanics and deal with more abstract attributes, such as generalized coordinates and their values [24].

For the realities investigated by classical electromagnetism, electromagnetic field vectors (in the general case, four vectors **E**, **D**, **B**, **H**) and electric charge remain their essential attributes. *Maxwell* equations connect those vectors. Previously discovered *Coulomb* law, *Faraday* laws of electromagnetic induction, *Biot-Savart-Laplace* and *Ampere* laws are cases of Maxwell electrodynamics. Since classical electrodynamics can be applied to condensed media, there is a need to include extra relevant attributes, such as electrical conductivity, dielectric, and magnetic susceptibility, etc. It should be noted that, despite the mathematical completeness and perfection of the *Maxwell-Hertz-Heaviside* theory [17; 25; 33; 29; 50], the science of electrodynamics continues to develop, being replenished with models of new attributes. For example, one can indicate the spatial and temporal dispersion of the dielectric permeability [1].

For the realities studied by quantum mechanics, the following attributes can be distinguished, in particular: spin and related phenomena, quantum tunneling, quantum discreteness of energy bound states, the exchange nature of certain interactions, *Heisenberg* uncertainty ratio, etc. The latter "forbid" simultaneous exact experimental determination of some pairs of attributes inherent in the classical description of macroscopic objects, e. g., spatial coordinate and momentum. This does not mean that quantum micro-objects exist outside the physical space, in which the macro-objects composed of them exist. On the one hand, we are talking about an additional connection between spatial and momentum coordinates of micro-objects (quantum realities) that is absent in classical mechanics. On the other hand, attributing classical behavior of spatio-temporal attributes of macroscopic realities to quantum realities complicates the description and explanation of experimental manifestations of the latter, while the human brain tries to squeeze those manifestations into the Procrustean bed of habitual ideas. As a result, the experiment does not confirm the classical interpretation of quantum realities. Instead, researchers observe a variety of patterns of non-classical motion and statistics of quantum objects [2; 9; 46]. One should not be surprised or grieved about this, because the world is exactly as it is, and you should study it, not by imposing your preferences on it, but by finding the laws and correlations inherent in the quantum world that surrounds us. After all, what we consider purely classical is essentially quantum-mechanical. For example, the very existence of condensed media is a manifestation of their quantum nature, since according to the *Earnshaw's* theorem [20], a neutral composition of positive and negative charges (combined into atoms and molecules, which, in turn, under certain conditions condense into liquids and solids) is unstable on any fluctuations in their location.

An interesting and understudied attribute of almost all realities known to modern science is their protean nature. Indeed, according to ancient Greek mythology, Proteus was a being who was able to transform into various animals and even into various things. Some sources state that he adopted a disguise depending on the circumstances and people he met. When one studies macroscopic realities, such as a certain big mountain, then we perceive, without any surprise, its different photos obtained from different distances and from different angles of view, as photos of the *same* mountain. One is not confused by various geological drawings and stratigraphic schemes that show the internal structure of the mountain on different scales. In fact, a similar perception occurs when studying microscopic realities such as atoms, atomic nuclei, and elementary particles. They show different composition, structure and behavior depending on the means and conditions of their experimental study. A certain generalization of this situation is the recognition of the essence relativity for natural realities. According to this relativity, realities show various manifestations of their essence, the study of which is necessary to develop adequate ideas about the reality attributes, actualized under certain conditions [32].

The ubiquitous manifestation of the essence ambiguity is the different aggregate states of substances. For example, on Earth such a common and important substance as water may be vapor, liquid, or ice, depending on the temperature, atmospheric pressure, concentration of impurities, etc. Another manifestation of this relativity can be associated with a well-known reality, the name of which is “atom”. Indeed, an atom, according to its name (the Greek word “άτομος” means “incapable of being divided”) is indivisible when it takes part in chemical reactions, that is, for energies lower than or of the order of several electron volts. Although in this case the state of the atom changes a little bit, but this concerns only the outer electrons, which also do not stray far from their maternal nucleus (actually, whether it is the “same” electron or its companion does not matter at all, because they are all identical). However (in its pure form, this can be observed for free atoms), a further increase in the exciting energy can overcome the binding energy of external electrons, so that the ionization of the atom occurs, that is, its transformation into an ion and one or more free electrons. Moreover, even this intervention does not lead to a catastrophe, since ions and electrons quickly recombine, restoring the earlier state. Another situation occurs when the external energy reaches mega-electron volts. Then the nucleus of the atom itself is excited or falls apart. As a result, the atom changes its specificity, becomes “different”. There is no need to talk about indivisibility in this situation.

Thus, it is expedient to consider everything natural, the existence of which is considered proven from a modern scientific point of view, as realities. Their examples are quarks, atoms, biological cells, planets, etc. Having recognized the independent objective existence of certain realities, scientists also admit the objective existence of their attributes. Here are some more examples of attributes. For quarks, those are color and flavor, for atoms – the electric charge of the nucleus, for cells – the presence of mitochondria, for planets – the distance from the central star. Note that the basis for distinguishing certain systems of scientific knowledge can be not only the realities of their subject areas, but also common attributes inherent in the realities of those subject areas.

Regarding the isolation of realities, let us consider modern atomic physics as a system of knowledge about atoms. Here, there are both general systems of knowledge, which consider the atoms of all elements, and specific systems of knowledge, which are limited to the study of individual kinds of atoms. As to attributes of the investigated realities, the result of objectification is common attributes of the latter. For example, celestial mechanics considers heavenly bodies only in terms of their *mechanical motions*, treating these bodies either as material points or as volumetric bodies of a certain shape that interact solely through a gravitational field. Modern celestial mechanics includes the study of not only regular movements, but also considers the inevitable instabilities of the celestial body trajectories if there are more than two bodies [15]. This approach neglects the rest of the physical attributes of celestial bodies and accompanying electromagnetic fields. Those attributes are investigated by other sciences astrophysics that emerged much later than celestial mechanics [31; 57]. Therefore, some attributes of heavenly bodies are “detached” from their carriers, and are, in this sense, abstract entities. They are objectified as material points or systems of material points. Within such an approach, only a crude approximation to real stars, planets, and comets can be obtained.

Quantum physics as a general approach to the surrounding world can serve as an example of the realm that arises because the isolation of attributes. It as a network of knowledge systems being more general than atomic physics, at least in two respects. Firstly, quantum physics includes systems of physical knowledge not only about atoms, but also about atomic nuclei, elementary particles, quantum gases, and quantum condensed systems. Secondly, to the extent that quantum physics includes various realities in its ramified domain, the latter, first, investigates certain common attributes of micro-objects or some macro-objects of different specific nature. For example, when studying certain either simple or even complex *models of metals*, we purposefully restrict ourselves by neglecting insignificant in this sense (by no means always insignificant!) feature of *Au* or *Na* metals. The study of such models is to some extent the study of attributes. For example, in the case of metals, it can be free electrons, plasma oscillations, strong *Coulomb* correlations between current carriers, etc. This statement is of a general nature and can be equally applied to other sciences. For example, when studying the taxon "*feline*" in zoology, a biologist sometimes can omit the specific features of an ocelot or a lion, focusing on the common features of felines, that is, isolating the common attributes of this family.

Therefore, the assumption, confirmed by the modern theoretical and experimental point of view, about the objective existence of realities is only the first step in their scientific cognition.

"Discovering" something in nature or society does not mean "knowing" it. The fact is that, regardless of whether the found *reality* is interpreted as elementary entity, as a complex one, or as an attribute, its scientific study consists in the isolation and careful study of the relevant *attributes*.

Scientific and everyday knowledge. The concept of "knowledge" has a distinctive character for persons with different educational training in abstract thinking. Indeed, when the average non-scientist claims to have acquired some mundane knowledge, he is also assuming that it is knowledge of "something", whatever the nature of that "something". However, if you ask her (him) why she (he) thinks so, then she (he) is not always able to explain the nature and origin of her (his) knowledge even about the realities that are nearby, not to mention those objects that are beyond her (his) sensory perception. It is typical for such a person to refer to what she (he) was taught in the family, school, or church, or to information that was contained in media reports or statements of acquaintances.

A more thorough answer to this question should be given by a scientist who has mastered systems of knowledge, that is, transformed them into his (her) own thinking, that is, forms of knowledge that he (she) uses to observe, analyze, and study external realities and obtain new knowledge about them. He (she) can report how certain knowledge was obtained, how it correlates with the realities of life, and what is the character and nature (not always!) of these realities. A scientist operates with knowledge structured into certain systems of knowledge, in particular scientific theories, which are characterized by specific types of systematization and features. Scientific systems of knowledge have a complex structure and can be divided into subsystems connected by a hierarchical multi-level organization. Scientific knowledge and its systems are varying collections of knowledge accumulated by the humankind, and therefore inherit such a feature as direction. What a specific system of knowledge is aimed at is its domain. During the development of science, systems of knowledge and ideas about their subject areas evolve simultaneously, that is, changes in each of them generate corresponding changes in others. For example, the introduction of a new verified model into the knowledge system leads to a clarification of ideas about the modeled subject and thus about the corresponding subject field, or even implies the existence of something new in it. On the other hand, the discovery of a certain reality or its attributes in the domain, unforeseen by the current system of knowledge, stimulates the rapid development of this system. In the case of the impossibility of the attribute interpretation within the frames of an (even updated) system of knowledge, the proper interpretation can be formulated outside the subject field of this system. Ultimately, the indicated collision prompts the creation of new systems of knowledge.

While constructing a new knowledge system, one should always be careful being limited by two extremes. The first one, formally dictated by the Occam's razor, consists in an oversimplification, which would lead to insufficient power and generality of the approach. The opposite limit is based on certain extremely complex models with many innovative ideas and many additional parameters that often makes results unsubstantiated. Such an extreme is the illness of modern theoreticians stimulated by the necessity of winning various grants. It was properly called the "inverse Occam's razor" [38]. The overcomplicated approaches often mimic the deep science rejecting from the outset simpler (but not primitive!) and more proper theories denounced as outdated.

A vivid example of the resistance of primitive intuition to the results of new science is the classical mechanics of Galileo-Newton, which all over the world begins is studied in high schools, but, surprisingly, is poorly mastered both conceptually and practically, even after receiving special technical education [39]. As pedagogues and psychologists found out, the views of the ancient Greek genius *Aristotle* reappear for each new generation of high school and university students. This is not surprising, because observations and experiments that measure the characteristics of motion in environments other than the vacuum (that is, everywhere) supposedly testify to the validity of *Aristotle* ideas, rather than *Newton* ones, about mechanical movement of ordinary objects. For example, the fact that we must exert a certain effort to move an object indicates that movement is possible only when a force acts on a body. Instead, *Galileo's* principle of inertia, i.e., *Newton* first law of mechanics, asserts that there are such frames of reference (so-called inertial frames), in which a body that is not influenced by any force will always keep a state of either uniform motion or rest. Every young person must *personally* pass the distance from *Aristotle* to *Newton*, while not being a genius as those great scientists. By the way, Aristotle's ideas about the action of force as a factor of constant motion are adequate for describing a moving body in a liquid, for example, in water [27; 44]. Intuition, which makes it possible to solve the problems of classical mechanics, must be constantly nurtured in oneself, attracting support from experimental facts, say, from astronomical observations.

Therefore, when talking about a specific system of scientific knowledge, it should be kept in mind that we are dealing with certain realities external to this knowledge, which can be roughly divided into two types.

The first one is knowledge about realities known even before the emergence of the corresponding system of knowledge. Thus, the existence of atoms was predicted long before the appearance of atomic physics as a network of systems of knowledge about atoms. Such preliminary knowledge has assumptions about the objective existence of realities (and, sometimes, about their attributes as well). After the construction of the system of knowledge, the realities concerned form its domain.

The second type of knowledge includes the creation, functioning and development of the knowledge system itself. For instance, based on experimental studies of atoms and using quantum theory to understand them, physicists developed such sophisticated and extensive systems of knowledge about atoms that, while not denying the existence of the latter, significantly changed the initial primitive ideas about these microscopic objects. Similarly, biologists created a synthetic theory of evolution, which includes both genetics and *Darwin*'s theory of natural selection as components. This theory is so powerful and so comprehensively supported by practice that the founders *Mendel* and *Darwin* themselves would have not been able to recognize it at once. Indeed, one component of the synthetic theory of evolution – modern molecular genetics – is a microscopic biochemical science [21], and the second component is speciation [37], which has absorbed many results of fruitful one hundred and fifty years of development. The state of science at the time of *Darwin* and *Mendel* was insufficient to conduct proper experimental and theoretical research at the modern level, although mental abilities of fathers' founders exceeded those of many nowadays researchers. Among many open questions in the theoretical biology, one can indicate the old good one about the possibility to reduce biology to physics. Although all living beings consist of elementary particles (the physical subject area), the new complexity arises, and the reduction is at least incomplete [48].

We take for granted the isolation of the preanalytical and analytical stages of the knowledge system formation [45]. In view of this division, we argue that a certain preliminary vision of the domain is created at the preanalytical stage of the knowledge system. At the next, analytical stage, when the first working sketch of this system already appears, there is an opportunity to ask precise questions about the attributes, i.e., features, connections, and properties of the investigated realities. Primal knowledge, which needs to be clarified, and sometimes even radically changed, forms ontic subsystems of scientific knowledge systems. Thus, in biology, its ontic system is the knowledge about the existence of living organisms and their species, in chemistry – about chemical elements and their compounds, in physics – about atoms and their types, in astrophysics – about cosmic bodies and their classes, etc.

Therefore, we must conclude that one of the fundamental features of scientific activity is its inherent continuity, due to which the participants in the knowledge process do not start their research from *tabula rasa* or a clean slate, although their predecessors might even be simply master craftsmen, curious peasants or priests interested in social progress and preservation of their domination. Scientists always rely on already tested and justified systems of knowledge and corresponding ideas about their subject field. Modern scientific cognitive activity consists either in development of earlier ideas and clarifying knowledge about relevant realities, or in attempts to expand the boundaries of the subject area by including new realities, some of which were hidden from previous research due to the insufficient level of the knowledge system. The description of these realities is created during the original cognitive activity. One also sees that science and invention are not separated by an immovable wall, but smoothly merge into one another. Thus, the professional training of a future scientist should include both the mastering of existing knowledge systems and the formation of certain views on the composition of their domains. Scientific theories play the decisive role in the indicated processes. As the prominent biologist *François Jacob* emphasized, "the process of experimental science does not consist in explaining the unknown by the known, as in certain mathematical proofs, it aims to give an account of what is observed by the properties of what is imagined" [Quoted 41].

One should pay attention to the significant difference in the perception of domains within everyday knowledge and systems of scientific knowledge. With the development of science, the discovered and investigated realities become increasingly distant from the realities that an average person, unarmed with modern complex scientific tools, can perceive in his community. Moreover, everyday ideas about qualitative and quantitative features of the observed realities are less clear and exact than scientific ideas about realities that are even beyond sensory perception. In modern life it is impossible to be limited to everyday or high-school-based knowledge. Only the study of the so-called general physics in universities can form ideas about the structure of elementary particles, condensed media, the near Cosmos, and the Universe, justified from a scientific point of view.

A prerequisite for the effective cognitive activity of researchers is the assimilation of plausible (*consistent with experiment or observation*) concepts developed by their predecessors about the researched realities. In this way, the belief in the objectivity and truth of the mentioned ideas is formed. In each of the modern sciences, there are certain undeniable statements, the rejection of which would mean the rejection of the corresponding sciences in general with all their achievements, methods and means of research. Thus, no scientist in the field of natural sciences doubts that a water molecule consists of an oxygen atom and two hydrogen atoms or that Venus is closer to the Sun than the Earth. However, even the question of whether water is H_2O is also not as simple as it seems [16].

Despite the great attention that philosophers of science and scientists pay to the question of the problematic existence of material realities, which is investigated by physics, we support *Louis Wolpert*'s point of view [55] about the incompetence of the philosophic intervention into the discussion of what does exist from the viewpoint of modern physics. There is no doubt that in the future scientists will refine their knowledge about the studied realities, but there are no scientific grounds to deny their materiality.

Conclusions. While studying scientific realities, scientists, similarly to artists, elucidate more and more details making the whole picture complex and, at the same time, attractive.

Moreover, both created pictures are productive and designed to improve our everyday life from the viewpoints of consuming and esthetics. In science, it is made by careful analysis of the reality attributes. This continuous path has no start and no end as Mother Nature itself.

We shall present comprehensive arguments in favor of our views in the monograph "Philosophy of Scientific Theories. The First Essay: Names and Realities".

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