Physical dimension of Sciences

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Abstract

A classification of scientific fields by the place that their typical objects occupy in three-dimensional space of physical dimensions: length, mass and time - in a logarithmic scale is proposed. Classification includes some areas of physics, chemistry, biology and geology, as well as history. The role of the areas that are not subject to the physical classification, for example, quantum mechanics is discussed. Natural interdisciplinary connections are established, as well as the gaps - the regions of space in which there are no objects of modern science. Conclusions about the comparison of scientific fields on the index of interdisciplinarity are made and recommendations on the assessment of scientific achievements by a wide audience are given.

1 Why physical dimensions?

The explosive growth in the number of scientific publications and mutual citations puts forward the task of an accurate approach to scientometrics. The prevailing approach based on the number of citations contributes to the concentration of efforts on already almost exhausted issues and therefore it is catastrophically not effective and leads only to the stagnation of science; a sense of stagnation is manifested in numerous statements of the crisis in various fields of natural science and humanities. The reason is that the lion's share of citations falls on very narrow areas, while the social effectiveness of science is determined by the synthesis of areas of knowledge, which is called a very vague and ambiguous term "interdisciplinarity".

Systematization of the Science is required to obtain fundamentally new knowledge about nature which can not be obtained within narrow areas. This arcticle is an attempt to show how such a systematization may look from the view point

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of physics. It is based on the binding of the subject of study to a certain range in length, mass and time.

Most of the scientific disciplines has its typical object of study, which has a certain size, weight and time of existence, so that we can identify a discipline with some area in three-dimensional space, with the coordinates of the form "centimeters", "grams" and "seconds".

Such disciplines we call metrizable. For example, atomic physics is metrizable. It deals with the atoms typical of which - the hydrogen atom has a size of about one angstrom and weight of about 10^{-24} grams. Processes investigated in atomic physics, for example, the electron transition with the emission of a photon have a characteristic duration about $10^{-12} - 10^{-11}$ second. We can associate with atomic physics the cuboid (parallelepiped with edges parallel to the coordinate axes) sized $10^{-8} - 10^{-7}, 10^{-24} - 10^{-21}, 10^{-12} - 10^{-11}$. That is, metrizable scientific discipline can be visualized as the area in three-dimensional space where on the coordinate axes are plotted accordingly, centimeters, grams and seconds that characterize the typical object of this discipline.

However, this approach is inconvenient in two ways. First, areas are very much different from each other and the picture will not be visible. Secondly, variation of objects within a field will be very large. For example, an oxygen atom will be more than ten times as hydrogen, and if we consider the excited state, then one hydrogen atom in the different states may vary by several times. Therefore it is necessary to represent the region on a logarithmic scale rather than an absolute scale. For example, atomic physics then will be associated with the cuboid $-8 : -7, -24 : -21, -12 : -11$.

Logarithmic scale solves mentioned difficulties. Even if we make a mistake ten times in assessing absolute size of the object of research, in the logarithmic dimensional lattice it will lead to an error of only one unit, which will hardly effect on the overall visual picture or the conclusions that are made based on it.

2 Dimensional classification of natural science and history

We start from the classification shown on the map of Russian science (MRS) [1], meaning not its content, to which there are many complaints, but the universal nature of classification itself. We note also that the MRS is not complete classification of even basic scientific areas. For example, MRS does not contain such clearly metrizable disciplines as quantum physics and anthropology. Physical measuring can not immediately reach all presented in MRS areas, so using some other, more complete system would not affect significantly to our conclusions. The binding of scientific disciplines to the dimensional lattice looks like this:

- **Physics**: Physics of elementary particles (ph): -20:-12, -25:-23, -20:3, nuclear physics (nu): -13:-12,-24:-21,-22:-21, acoustics (ac): 3:4,0:-2,-2:-4, atomic physics (at): -8:-7,-24:-21,-12:-11, molecular and chemical physics & physical chemistry (mo): -7,-23:-21,-12:-7, optics (op): -4:-3,0,-8:-7, astronomy and astrophysics (as): 9:20,23:40,5:18, physics of liquid, gas and plasma (li): 0:4,-3:9,-2:2, physics of condensed state (co): -4:2,-4:3,-7:2.

- **Chemistry**: electrochemistry (el): -2:0,-3:0,-1:2, analytical chemistry (an): -3:-1,-3:0,-1:2, crystallography (cr): -7:-1,-23:-3,-3:10, inorganic chemistry (no): -8:-6,-24:-20,-9:-7, organic chemistry (org): -7:-5,-22:-20,-8:-6, polymers (po): -5:0,-20:-1,-6:3.

- **Biology**: mycology (mico): -3:1,-4:2,2:4, microbiology (micr): -6:-4,-21:-12,-3:3, botany (bo): -1:3,-2:7,4:9, ornithology (orn): 0:2,0:4,4:5, biochemistry and molecular biology (bi): -7:-6,-21:-20,-8:-7, ecology (ec): 6:9,12:16,7:10, cytology (ci): -4,-12,2:9, virology (vi): -7:-6,-20,1:3, zoology (zo): 1:3,2:7,7:9, entomology (en): -2:1,-6:1,7.

- **Various geology**: oceanography (oc): 7:9,13:14,13:14, paleontology (pa): 0:3,0:4,13:16, geology (ge): 0:9,24:25,16:17, meteorology and atmospheric sciences (me): 9,13,6:7, mineralogy (min): -1:1,-2:3,13:16,

- **History**: history (hi): 6:9,10:14,7.5:11.

This classification is approximate, but not arbitrary. It can be clarified by analyzing the content of scientific papers on these subjects (in the exact natural sciences, for example, [2]) and specifying to which specific object the considered method are applied. For example, the history deals with groups of people about a hundred thousand to a billion, so the logarithm of mass varies from 10 to 14; historical events tend to affect the distance of about ten to ten thousand kilometers (logarithmic scale variation from 6 to 9), and the time from one year untill about a thousand years (7.5:11). Events of smaller scale (like a disease Of Vladimir Lenin) are of interest to history only due to obvious consequences that they imply in tagged scales (e.g., the power struggle in the USSR), and therefore are not, in fact, the subject of history - here historians turn to other disciplines, such as ecology, psychology, or microbiology.

Figure 1 shows these areas in a common coordinate system. It can be seen that the physics of elementary particles and astronomy-astrophysics represent two extreme disciplines indicating the limits of known Nature, and other disciplines are located between them. The total area occupied by metrizable disciplines, is no more than a few per cent of the total volume.

It is interesting to trace the area of intersection of different disciplines. Interdisciplinary index (Ii) of a point l, m, t in the dimensional space is the number of disciplines, which areas contain a given point. Figure 2 shows the regions with $Ii = 2, 3, 4, 5, 6$. Disciplines are identified by the first two - four letters of the name.

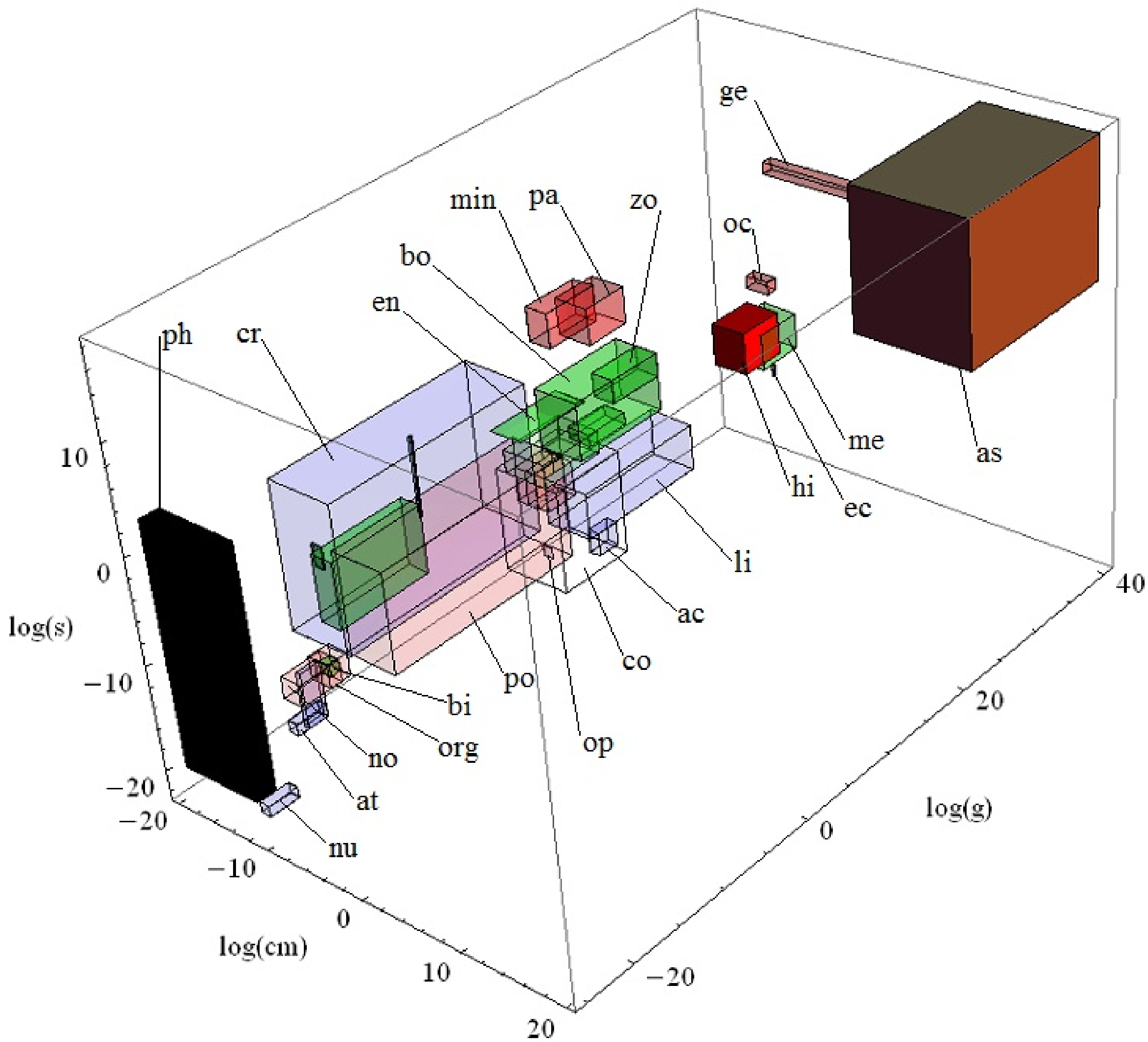

Figure 1: Dimension classification of disciplines

For example, the class $Ii \geq 5$ contains the following combinations of disciplines: *an co cr el po, co el li mico po, an co cr el mico, an co el mico po, an co cr el mico po, co cr el mico po, an co cr mico po, an cr el mico po*, the class $Ii = 6$ (maximal at the given index) contains only one combination: *an co cr el mico po*.

If some point belongs to two different disciplines, this indicates that the methods of both disciplines are applicable to the scenarios corresponding to this point. This indicates a certain adhesion between these disciplines, and the principal possibility to apply the methods of one of them to objects that formally belong to another discipline. The index of interdisciplinarity Ii, which we assign to any discipline, is not a characteristic of its only one; it is an integral characteristic of the place of this discipline among others.

Another characteristic of the scientific field is its trans-disciplinary nature. Trans disciplines are not well metrizable. Such disciplines directly operate with objects from very different metrizable areas. Trans-disciplines include physics, along with its constituent mathematics, as well as biology.

3 Discussion and conclusions

It is the time to draw some conclusions. The division of disciplines into metrizable and non-metrizable is nontrivial. This division does not correspond with the division into natural and humanitarian disciplines, because, for example, biophysics turns hardly metrizable, the main natural discipline - mathematics is non-metrizanle, whereas the history is well metrizable. Metrizable disciplines, which can be called primary play the special role because within them the achievements of science are realized - with direct conscious manipulation with a specific object, and not with abstractions. Therefore, their characteristic - the index of interdisciplinarity - is practically important.

Figure 1 shows how insignificant volume of the entire space is occupied by the metrizable part of modern science. If we figured, in addition to science, also the directions of the human activity (technologies, etc.), the covered area would not change much, because applications in dimensional grid are grouped around (and even inside) tagged fundamental domains. This indicates a superficial penetration of the modern civilization into the world around us.

If $Ii > 1$ for some disciplines, it says that the methods of one discipline could potentially be applied to the study of objects belonging to the other discipline.

For example, the presence of the intersection between the history and the ecology suggests the possibility of reliable explanations of historical events through environmental causes. Resettlement of people from the Sahara to north was connected with desertification of large areas of previously fertile land. But if the possible causes of historical events related, for example to microbiology, one can hardly expect an equally reliable explanations. Were the tumultuous events in the Soviet Union in the 20-s consequence of Lenin's illness and whether the infection alone caused his

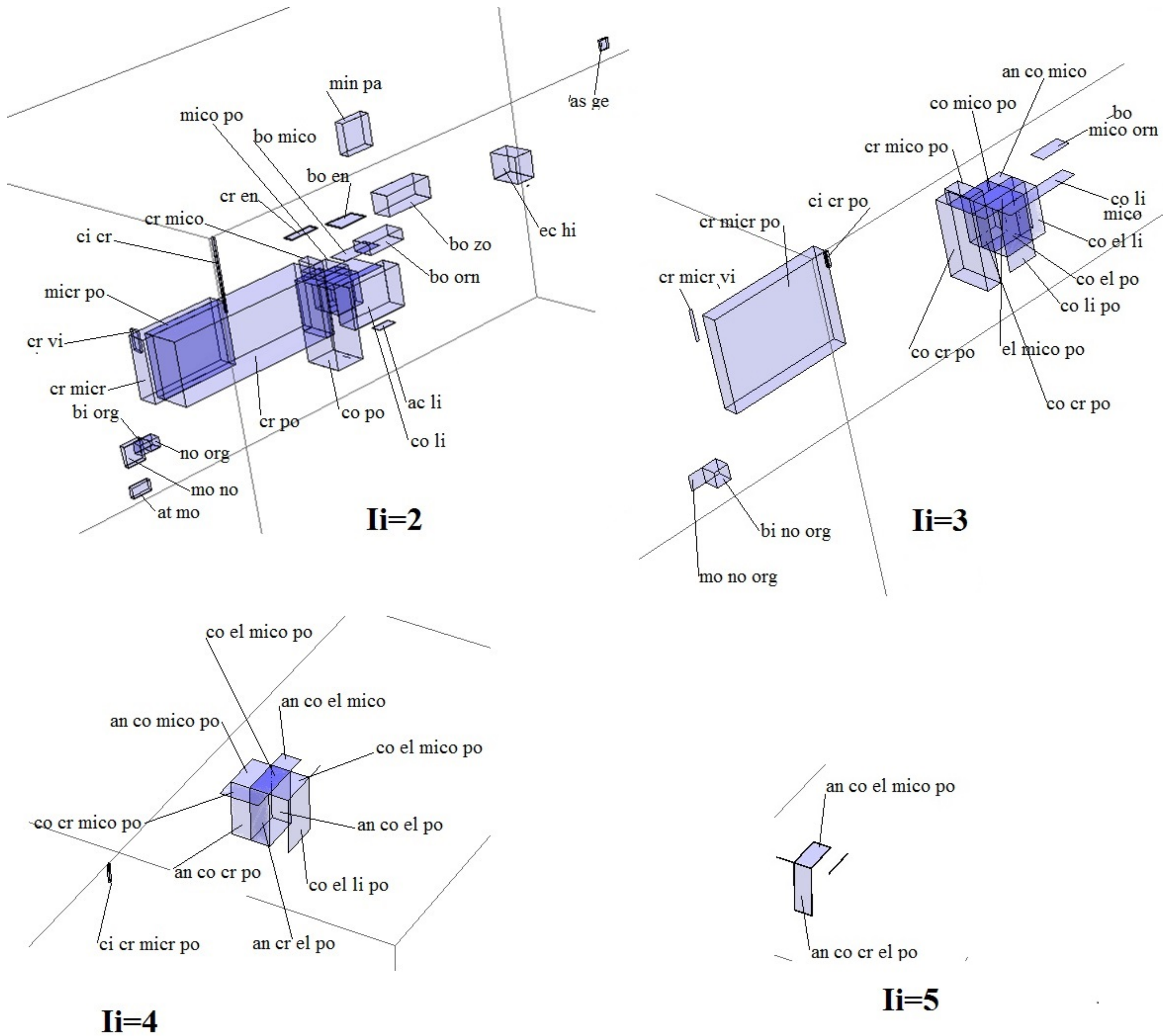

Figure 2: Inter-discipline index ranking

death? Here nothing definite can be said: the history and microbiology have no points of intersection in dimensional grid; the considerable space separates them, and methods of one of these disciplines do not apply to the other directly.[1].

Interesting areas has a high index of interdisciplinarity $Ii > 1$, because here fundamentally different methods can be applied to the same objects. For example, in the area of maximum $Ii = 6$ got along with electrochemistry, crystallography, analytical chemistry, condensed matter physics and polymer also mycology.

This suggests that fungi have some properties that distinguish them from the whole animal world. Namely, their direct description is closely related to many areas of knowledge: analytical chemistry, electrochemistry, condensed matter, polymers, and - in part, with crystallography. This may suggest that fungi is a convenient experimental platform for modeling the interaction of living and non-living matter.

The second conclusion is that the properties of the living are closely related to crystallography, polymers and condensed states - disciplines that are very important for the study of the Earth, that is, geology in the broad sense of the word. At the same time, geology in the broad sense is divided into separate formal areas rather far from each other: oceanology, paleontology, geology itself, which indicates the patchwork nature of the study of our planet and the methodological weakness of traditional approaches to this study, in fact leaving behind the most important areas of knowledge.

It may be surprising that cytology (identifier "ci") is not included in the list of sciences with a high degree of interdisciplinarity. Of course, this does not mean that there is no need for chemistry and physics, just the opposite! But this fact suggests that the application of methods of exact natural science (chemistry, physics) in the form in which they are now developing, to a living cell is difficult. Methods of exact natural science have developed and are developing with the expectation of instrumentation - devices made by man, not biological objects.

Remarkable observations can be made about history. History in its technological aspect is politics. From the view point of natural science, politics is the practical realization of history within the thinking of the ruling class. It is not surprising, therefore, that the very view of history depends on politics, and on the biased position of those who rule. History is nothing more than the fixation of political actions with a certain precision, and this accuracy has an objective limit associated with the said reverse influence. Its good metrizability indicates that political activity also fits well into the proposed dimensional classification of natural science, and, consequently, methods of natural science are applicable to politics, despite the limits of the accuracy of fixing the events themselves and their details (for example, disputes about losses in wars).

This confirms the fact that significant discoveries in the natural sciences go hand in hand with political changes. This is especially noticeable in the case of quantum

[1]"What about the impact of the plague on the historical process ?" - the historian exclaims. Plague epidemic affects the history only through zoology and ecology; microbiology does not directly affect the history, only to a particular person.

physics and relativity, as well as genetics; the very formation of these disciplines did not accidentally coincide with the turbulent political events of the first half of the 20-th century; it is likely that these events themselves can be considered as the consequences of scientific discoveries, formally not related to politics - namely scientific discoveries, and not their technical implementation, like the creation of new types of weapons.

Another observation concerns medicine. This practical area concerns many parts of biology, such as virology and ecology, which themselves do not have intersections in metric space. Medicine, therefore, is not a well-metrizable field of human activity. Its synthetic character and connection with the fate of individuals, as well as the great importance in the life of entire countries distinguishes this sphere of human activity among all others. Medicine, of course, should be considered as a field of practical biology and belongs to the trans-disciplines.

The general area occupied by metrizable disciplines is no more than a few percent of the volume of the entire dimensional lattice, if we move to real rather than logarithmic dimensions. Outside of tiny metrizable peace of space there are huge space-temporarily-massive field, possible processes in which are not covered by science, and thus remain outside of our perception. This indicates the limitations of existing scientific methods. For example, a huge lacuna corresponds to fast processes covering long distances, which may correspond to nonlocality arising from the entanglement of quantum states (see [3]) - a phenomenon whose significance has not yet been sufficiently studied. Another lacuna is located in the region of short times and large masses, which corresponds to compact massive objects such as "black holes".

Another similar lacuna is located in the region of small distances or small masses and large times. It corresponds to the states of microscopic particles of matter, which having a huge lifetime, can still slowly change, in particular, the characteristics of elementary particles. An example is the spin states of atomic nuclei, which can live for hours, as well as special quantum states of small charge ensembles, free from decoherence and able to exist for a very long time.

We believe that it is in this kind of "lacunae" of modern natural science that phenomena of critical importance for our civilization can be located. The possible path to these fields, the path to empowering already existing areas, lies in taking into account the strong scaling factors of existing models far beyond their recognized applicability. For example, it takes into account the electromagnetic field in full when modeling chemistry, or quantum entanglement of micro-objects, which can cover billions of particles. The most important phenomenon, which, perhaps, to a great extent allows such extrapolation, is life itself. The nonlocality of life is perhaps the most fundamental factor in its understanding.

Modern natural science is at the beginning of stagnation. Semiconductor electronics and IT technology based on it, nuclear energy and limited manipulation of the genomes of edible plants and bacteria have exhausted a large part of the significant achievements of the 20-th century. Ultimately, we meet the weakness of our understanding of micro-processes running in complex systems. It is here that the only proven starting position is quantum mechanics, and the urgent task is to extend it to complex systems. Experiments clearly show that we cannot overcome this barrier by Feynman quantum computer without serious reconsideration of its scheme, since we do not understand exactly how quantum physics works in complex systems.

We can see that the largest natural disciplines: mathematics, physics, chemistry and biology are trans-disciplines. They are very general, and the difference between them characterizes not only their objects, but also their methods. Actual scientific work is carried out in more specialized metrizable areas. But it's not just about metrizability; special disciplines also narrow the scope of possible searches. For example, the problem of chemistry: what happens if you push a few dozen atoms of different elements with known initial conditions, refers to a very complex problems of quantum scattering theory, of which only the case of three bodies is currently solved, and its solution is very complex (see. [4]).

The outcome of a chemical reaction may depend on the initial conditions, up to the angle at which two molecules approach each other; it also depends on the joint state of the molecules and the electromagnetic field. But in biochemistry, the degree of uncertainty is much less: there are polymers with a rigid structure and low-molecular ligands. The rigid structure of the polymers - protein molecules or nucleic acids sharply narrows the possible variety of initial conditions.

And if we consider biology - at the chemical level, the uncertainty will be even less, because not all processes involving polymers are essential for life; in the living there is a constant release from unnecessary substances with complex internal processes, which, thus, are removed from the field of view of the biologist. Support for homeostasis within the cell is very rigidly determines the possible chemical reactions, and the immune system severely limits the possible diversity of proteins.

Due to the strict regulation of possible reaction channels, modeling biology seems to be a simpler task than the general task of chemistry. This is one of the reasons we believe that, despite the seemingly overwhelming complexity of the problem, we have a chance to discover the quantum mechanism of biology.

The main trans-discipline, mathematics, determines the accuracy of our knowledge of mechanisms in various fields. Currently, the most accurate is quantum physics, in the scope of which is the methods of chemistry, materials science and - potentially - biology, together with their applications. For the development of these areas physics must change radically; perhaps even the name of quantum mechanical methods in application to such areas will be special in the near future. And nuclear physics has not yet got into the sphere of accurate, quantum methods; although it is a major military factor for humanity, it remains an empirical discipline, and progress there can be expected at a later time.

This feature is also connected with the fact that for the chemical-biological sphere (roughly speaking - atomic physics) there are many possibilities for setting up an experiment, while for manipulations with the atomic nuclei there are no such possibilities: the transformation of nuclei occurs in deep Space, and we can only observe the results of such processes.

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