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NEWTONIAN CELESTIAL MECHANICS AS A COMPONENTIAL PROTOTYPE OF SPECIFIC THEORIES

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Abstract. Any scientific theory in the natural sciences is an artificial, complex, and abstract construct, consisting of many components (ingredients, constituents, structural elements). It is developed by scientists to gain and comprehend experimentally verified new knowledge about its domain of study. It is helpful to distinguish between two meanings of the term "theory". The application domains of specific theories include particular kinds of realities. Examples include Newton's celestial mechanics and various classical, quantum, and quantum-relativistic theories of gases, fluids, molecules, atoms, and elementary particles (theory of atomic spectra, Bohr's atomic theory, Planck's quantum theory of black-body radiation, quantum theory of the hydrogen atom, quantum-relativistic theory of black holes, etc.). The names of specific theories usually include the names of the types of realities they study. Abstract theories serve as general frameworks for a group of specific theories of the same kind (in particular, macroscopic, microscopic, or megascopic kinds). Examples of abstract theories are classical mechanics, quantum mechanics, and the theories of relativity, which act as common frameworks for concrete theories from classical, quantum, and quantum-relativistic physics, respectively. The article compares concepts of complex structure and development of specific theories with notions of structure and development of automobiles. Such a comparison is more useful and heuristic than analyzing theories in terms of paradigms or interdisciplinary matrices, which, in any case, are not part of scientific theories. The work employed **methods** of terminological and content analysis of the original text of Newton's *Principia* and the comparative method. **The aim** is to consider Newtonian celestial mechanics as the last universal common ancestor (LUCA) of all particular specific theories. The role of Euclidean geometry as a potential LUCA for abstract theories will be explored in another article. An analysis[1] of Newton's *Principia* showed that celestial mechanics encompasses a wider range of components than physicists and philosophers of science typically consider part of a theory. **Main results.** Taking this theory as a prototype for all specific theories, the article demonstrates the existence of sixteen types of components within it. Components of the same type form a specific subsystem of the theory as a polysystem. In any specific scientific theory, all these subsystems together constitute an interconnected whole that is necessary but not sufficient for generating

[1] Габович О., Кузнєцов В. Філософія наукових теорій. Нарис перший: назви та реалії. Київ: Наукова думка, 2023. 520 с.

new knowledge. **Conclusions.** The article is of a historical-scientific and theoretical-cognitive nature, and the results obtained can be applied in research on the history and philosophy of science, as well as in the teaching of natural science disciplines.

Keywords: Newton, celestial mechanics, scientific theories, cars, complexity, change, polysystem, subsystems, component, development.

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НЬЮТОНІВСЬКА НЕБЕСНА МЕХАНІКА ЯК КОМПОНЕНТНИЙ ПРОТОТИП КОНКРЕТНИХ ТЕОРІЙ

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Анотація. Будь-яка наукова теорія з природничих наук – це штучна, складна та абстрактна конструкція, яка утворена з багатьох компонентів (інгредієнтів, конституєнтів, структурних елементів). Вона створена вченими для отримання та розуміння експериментально перевірених нових знань про її сферу дослідження. Корисно розрізняти два значення терміна «теорія». Галузі застосування конкретних теорій включають певні види реалій. Прикладами є небесна механіка Ньютона та різні класичні, квантові та квантово-релятивістські теорії газів, рідин, молекул, атомів та елементарних частинок (теорія атомних спектрів, атомна теорія Бора, квантова теорія випромінювання чорного тіла Планка, квантова теорія атома водню, квантово-релятивістська теорія чорних дір тощо). Назви конкретних теорій зазвичай включають назви типів реалій, які вони вивчають. Абстрактні теорії служать загальними рамками для групи конкретних теорій одного типу (зокрема, макроскопічного, мікроскопічного або мегаскопічного типу). Прикладами абстрактних теорій є класична механіка, квантова механіка та теорії відносності, які є загальними рамками для конкретних теорій з класичної, квантової та квантово-релятивістської фізики відповідно. У статті порівнюються концепції складної конструкції та розвитку конкретних теорій з уявленнями про будову та розвиток автомобілів. Таке порівняння є більш корисним та евристичним, ніж аналіз теорій з точки зору парадигм або міждисциплінарних матриць, які, в будь-якому випадку, не є частинами наукових теорій. У роботі використано **методи** термінологічного та контент-аналізу оригінального тексту Ньютонівських «Principia», а також порівняльний метод. **Метою** є розгляд ньютонівської небесної механіки як універсального спільного предка (LUCA) усіх конкретних теорій. Роль евклідової геометрії як потенційного LUCA для абстрактних теорій буде досліджена в іншій статті. Аналіз «Начал» Ньютона показав, що небесна механіка охоплює ширший спектр компонентів, ніж фізики та філософи науки зазвичай вважають частинами теорії. **Основні результати**. Беручи цю теорію за прототип для всіх конкретних теорій, стаття демонструє існування в ній шістнадцяти типів компонентів. Компоненти одного типу утворюють конкретну підсистему теорії як полісистеми. У будь-якій конкретній науковій теорії всі ці підсистеми разом утворюють взаємопов'язане ціле, яке є необхідним, але недостатнім для генерування нових знань. **Висновки**. Стаття має історико-науковий та теоретико-пізнавальний характер, а отримані результати можуть бути застосовані в дослідженнях з історії та філософії науки, а також у викладанні природничо-наукових дисциплін.

Ключові слова: Ньютон, небесна механіка, наукові теорії, автомобілі, складність, зміна, полісистема, підсистеми, компонент, розвиток.

All that has happened since 1687 is a gloss on the *Principia*
Steven Weinberg

Introduction. We state that the car metaphor, rather than the paradigm one, is more heuristic for the historical and philosophical analysis of theories.

Indeed, let us consider a complex and artificial material system, such as a car. It was constructed as an assemblage of previously known cart components and new components necessary to produce the whole thing. The first group of elements consists of the wheels, the frame, and the body, whereas the second one includes the combustion engine, the steering and braking systems, the fuel tank, and the fuel supply equipment. At the same time, there were changes in the substance from which the previously existing subsystems were made, e.g., metal or plastic details replaced wooden ones. The construction and creation of the new subsystems of the car require the invention and production of previously missing materials (different kinds of alloys and ceramics for engines, rubber for wheels, and various tubes).

After the first cars were built (invented independently by several engineers), subsequent, more sophisticated cars were produced in two interrelated ways. On the one hand, designers and engineers improved the already existing subsystems of a car (the engine, wheels, brakes, etc.). On the other hand, they invented and constructed new ones (automatic transmission, radar-parking system, computer subsystem to monitor the functioning of the whole body, etc.).

It would not be an exaggeration to assume that the intentional construction of any human-made complex small (kitchen plate, fridge, and fan) or large systems (language, society, art, irrigation, agriculture, industry, trade, education, technology, science) undergo the same development stages as cars described above. However, all such stages are performed through both unconscious and willful human-made changes in their previously existing subsystems, as well as via the creation of new subsystems. By default, all these changes adhere to natural laws and utilize the intrinsic properties of the substances used in the construction and operation of the subsystems in question.

A system, at least one element of which is itself a system, is a polysystem. Such a system is a subsystem of the polysystem. Identifying subsystems of a polysystem, such as a car, and tracing their development and connections stimulates experts to write the objective and not yet fully investigated history of the car's evolution. The full version of this story would describe the stages of car development in terms of the connections between their "old" and "new" subsystems (this opposition is time-dependent).

As a rule, any specific modification of cars is done step by step and initially concerns only several car subsystems. Producing cars with modified subsystems and testing their expediency and effectiveness through market mechanisms (the customer demand) stimulates other competitive car producers to introduce new subsystems into their products and further modify these and other car subsystems. In modern society, all modifications are made by individuals or companies and are protected by patent law.

Another situation arose when inventors built their first aeroplanes. This event was a truly revolutionary phenomenon. Indeed, until a certain time, the creation of flying objects that are heavier than air was considered impossible. Even now, the natural construction of beautifully flying birds cannot be easily mimicked. New approaches to creating artificial "birds" emerged soon. The realized flying ability was based on the successful development of aerodynamics[2] and had little to do with the bird's wings.

However, even in this quite different case, the invention and creation of a new kind of conveyance became possible only using already-known car subsystems. First, we refer to internal combustion engines. Other subsystems borrowed from the car (control system, wheels, body) required radical restructuring and new physical materials to implement their functions in new conditions and preserve the lives of pilots and passengers. At the same

[2] Weltner K. A comparison of explanations of the aerodynamic lifting force. *American Journal of Physics.* 1987. Vol. 55. № 1. P. 50–54. doi: 10.1119/1.14960.

time, certain similar subsystems, such as airbags in cars and evacuation slides in aeroplanes, emerged in parallel and utilized common physical principles and materials.

This seemingly mundane story demonstrates how complex systems emerge and develop in knowledge-intensive industries. Upon closer examination, one can find analogous subsystems and their components (in most cases, not structureless) in scientific theories inherent in the natural sciences. That is why it is instructive to identify the subsystems of a theory as the polysystem and to build a genuine metatheory of theories not based on abstract philosophical reflections or a single notion of grammar and a simplified view of real scientific theories, but necessarily and explicitly taking into account their complexity.

In a certain sense, the analysis of the creation and evolution of any complex artificial material system sets a perspective reference frame for the study of scientific theories. Such a system is more suitable for modelling their nature, internal structuring, properties, functions, interrelations, development, and applications in comparison, for example, with the overused concept of paradigm[3]. The latter is only a single and not a principal or universal grammatical rule. Anyway, the rule of the composition of correct sentences made of words is more important than the paradigm rule. The adaptation of this syntactic rule to the explanation of history and the development of science does not fit the nature and specificity of both language and science. On the one hand, the application of a single grammatical rule chosen among linguistic rule systems overshadows their relationship and lowers its heuristic potential. On the other hand, assigning a central position to the paradigm concept introduces a plethora of lateral concepts that are absent in science, thus distorting its nature and the relationship between different sciences. For instance, it concerns the concept of incommensurability between classical and quantum theories, as well as the idea of scientific revolutions. Let us look more closely at these two crucial statements disproving Kuhn's approach. First, the apparent "crucial" difference between classical and quantum physics is senseless, since the very existence of the condensed matter has essentially a quantum nature. It was tacitly assumed in basic classical physics but was not explicitly explained. The recognition of this fact took a lot of time and gradually became clear to all involved scientists. However, no barrier between classical and quantum physics exists in this case. Second, there were no scientific revolutions in Kuhn's sense. For instance, the generally accepted interpretation of quantum mechanical phenomena does not exist even now, more than a hundred years after the birth of Planck's constant. The problem of quantum measurement is still under discussion and far from being solved.

There is no doubt that the notion of a paradigm seems understandable and extremely attractive to non-scientific audiences, but it oversimplifies science and its history. However, "simplicity comes at a cost: it distorts the image of science, how the scientific process actually works and how we foster new advances"[4].

Celestial mechanics is the prototype of all subsequent scientific theories. Newton's *Principia* has had a profound impact on the modern Western worldview and science, rivalling that of the *Bible*, Plato's *Socratic Dialogues*, Aquinas's *Summa Theologiae*, Copernicus's *On the Revolutions of the Heavenly Spheres,* and Galileo's *The Dialogue Concerning the Two Chief World Systems*[5]*. Concerning physics as the scientific background of our civilization, "Newton gave us more than just an empirically successful theory of mechanics – he gave us an account of what knowledge of the physical world should look like, one that remains with us. But what is this account of physical knowledge? What is it that remains with us?"*[6].

[3] Kuhn T. The Structure of Scientific Revolutions. Chicago: The University of Chicago Press, 1962. 222 p.

[4] Krauss A. Science of Science: Understanding the Foundations and Limits of Science from an Interdisciplinary Perspective. Oxford: Oxford University Press, 2024. 193 p.

[5] Einstein A. The mechanics of Newton and their influence on the development of theoretical physics. / A. Einstein. *Ideas and Opinions*. New York: Crown Publishers, 1954. P. 253–260; Weinberg S. Newtonianism and today's physics. / Eds. S. W. Hawking, W. Israel. *Three Hundred Years of Gravitation*. Cambridge: Cambridge University Press, 1989. P. 5–16.

[6] Samaroo R. Newtonian mechanics. / Eds. E. Knox, A. Wilson. *A Companion to the Philosophy of Physics*. New York and London: Routledge, 2022. P. 8–20.

To answer the last question, one should note that Newton's celestial mechanics is a complex, specific theory. The entities it describes are the space-time trajectories of planets, as observed by the telescopes of his time. There were no ideas about the physical properties of planets except for their mass, spatial locations, and relative motions.

Based on *Principia's* text, we wish to answer Samaroo's question. Our response focuses on identifying the internal composition of celestial mechanics in the most comprehensive manner possible. Its types of components serve as a universal, necessary template for all current and future physical theories. However, much more is required to classify some abstract and promising constructions with such ingredients as genuine scientific theories. They must undergo a long, complex, and often contradictory process of experimental or observational confirmation, which is never absolute or final. The proposed construction can fail in light of new data obtained from new original observations and experiments conducted with new equipment. To this end, it is worth recalling that the accuracy of Henry Cavendish's famous 1798 gravitational force measurements was surpassed only at the end of the nineteenth century, whereas certain measurement problems persist even now[7].

In physics, experimental activity, along with the creative use of various mathematical languages, is an obligatory partner to real theoretical work. This is the practical and historical argument that the template in question will continue to be a constantly improving working tool for physicists to obtain new knowledge. The presence of these components in any physical theory is a specific illustration of Planck's[8] declaration of the unity of the physical world.

It is indisputable that the contents of inner components and their functioning in specific theories such as electrodynamics, special and general relativity, statistical physics, and quantum mechanics differ from those of classical mechanics in their peculiarities and factual complexity. However, they belong to the same general kind, called physical theory. It consists of a network of interconnected, specific, and permanently developing theories across different domains and maturity levels. In other words, thus far, new concepts and ideas have been successfully integrated into the existing system-componential pattern of a theory. We would be grateful to readers for informing us about working cognitive tools that serve as alternatives to this pattern.

If an original idea cannot be expressed in terms of one of the necessary components of an existing theory, eventually it becomes a trigger for the formation of a new theory. For example, one may cite the emergence of quantum theory as a result of Planck's idea of energy discreteness at the microscopic level.

Newton's *Principia* is the text that expounds the first practical theory of motion, specifically the theory regarding the motion of material celestial bodies, such as planets and their satellites. Considering their mass, spatial trajectories, temporal changes in trajectories, accelerations, and forces between them, it does not address other planetary attributes (spatial size and form, materials from which they are composed, etc.). In view of this, it is merely an approximate representation, confirmed by then-available quantitative observations, of the actual Solar System and the phenomena within it.

Modern versions of celestial mechanics (for example, the theory of orbital motion[9]) operate much more deeply and accurately. It concerns both its original domain (for instance, calculation of the distance between the Earth and the Moon with an accuracy of a centimeter and the phenomenon of the instability of the solar system) and other topics (the movement of stars and galaxies, artificial satellites, their landings on other planets and asteroids, and their return to Earth, etc.). In the latter cases, physicists also use the theories of relativity and data on the physical attributes of the interplanetary medium. It would be wrong to evaluate

[7] Cook A. H. Experiments on gravitation. *Reports on Progress in Physics*. 1988. Vol. 51. № 5. P. 707–757. doi: 10.1088/0034-4885/51/5/003; Speake C., Quinn T. The search for Newton's constant. *Physics Today*. 2014. Vol. 67. № 7. P. 27–33. doi: 10.1063/PT.3.2447.

[8] Planck M. Eight Lectures on Theoretical Physics Delivered at Columbia University in 1909. New York: Columbia University Press, 1915. 139 p.

[9] Roy A. E. Orbital Motion. 4th ed. Boca Roton: CRC Press, 2004. 544 p.; Wells J. D. Effective Theories in Physics. From Planetary Orbits to Elementary Particle Masses. Heidelberg: Springer. 2012. 84 p.

even these versions from the perspective of the concept of absolute and final truth. They are only an approximation to reality.

Let us turn to the so-called system-component reading of celestial mechanics, as set out in the *Principia*. By such reading, we mean the careful, unquestionable and grounded selection of its components, in fact, subsystems consisting of the components of the same type. Their existence, not always evident, along with their interrelations and mathematical descriptions, provides unprecedented explanatory and predictive power for this theory. Indeed, it explained, clarified, and linked the quantitative data of astronomical observations of planetary motions, accumulated over many centuries, into a single whole.

The *Principia* is the componential archetype/prototype and probably the last universal common "ancestor" (LUCA) of all physical theories that appeared after it. This means that they ought to include the same types of components as Newton's theory.

Components of celestial mechanics according to *Principia*. There are many versions of classical mechanics, from the simplified "high school one" to "university-level treatises" designed for future scientists and engineers. It is worth distinguishing "theoretical mechanics" as a knowledge kit destined for engineers and "classical mechanics" as an integral fundamental part of theoretical physics. Brilliant people created these very sophisticated branches of mechanics.

So let us briefly consider the Newtonian *Principia*, Mathematical Principles of Natural Philosophy[10]. This work summarizes the ideas accumulated by Isaac Newton regarding his subject, namely, celestial mechanics. Specifically, "obvious" and "indisputable" statements (actually, estimates[11]) are put forward about the objective existence of natural bodies in space and time, the motion of which obeys the dependences that this science formulates in the form of laws. Of course, better than anyone else, Newton understood the uncertainties of his formally axiomatic construction. However, he had to take a decisive step to create a great science that is alive now and seems to survive humankind. Still, he discussed the crucial problem of choice between short-range and long-range action and the accompanying concept of ether, making a reservation. "*Hypotheses non fingo*." In this connection, it is a pity that scores of scholars cite this statement out of its proper context, rendering it senseless.

Practical modifications of the Newtonian Universe appeared only in the twentieth century and were no less significant. We mean special and general relativity[12], quantum mechanics[13], and quantum field theory[14]. Of course, they did not cancel classical mechanics in the sphere of its application.

The system of physical knowledge established by Newton assumed that the properties of bodies (in our terminology, entities, i.e. long-lived physical objects and their persistent attributes with variable quantitative values) do not depend on where, when, and by whom they are examined. It is an ontic hypothesis about the component of the Universe, the experimental refutation of which goes beyond any practical actions of humankind. The conviction of its universal applicability is based on the consequences of its applications in the natural sciences, which have confirmed the majestic and unified picture of the Newtonian Universe.

This worldview contradicts the dogma of Christianity (as well as other Abrahamic religions) about the uniqueness of the Earth with humans on it, a dogma that Newton himself probably believed. Much has been written about the complex matter of the great thinker's religious views. For this purpose, it would be beneficial to read at least one small book[15]

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[10] Newton I. The Principia. Mathematical Principles of Natural Philosophy. Oakland: University of California Press. 1999. 994 p.

[11] Габович О., Кузнєцов В. Від загальних наукових цінностей до конкретних теоретичних оцінок. *Логічні, онтологічні та аксіологічні виміри наукового пізнання*: колективна монографія / за ред. Гардашук Т. Київ: Наукова думка. 2025. (У друку).

[12] Thorne K. S., Blandford R. D. Modern Classical Physics. Optics, Fluids, Plasmas, Elasticity, Relativity, and Statistical Physics. Princeton: Princeton University Press, 2017. 1552 p.

[13] Gasiorowicz S. Quantum Physics, 3rd ed. Hoboken, NJ: John Wiley and Sons, 2003. 352 p.

[14] Zee A. Quantum Field Theory, as Simply as Possible. Princeton: Princeton University Press, 2023. 432 p.

[15] Manuel F. E. The Religion of Isaac Newton. Oxford: Clarendon Press. 1974. 147 p.

to make sure that Newton was a devout Christian who believed in the power of God and his desire to allow humankind to know God's will concerning the physical world. At those times, such thoughts were dominant in the Western countries[16]. It is worth listening to Frank Manuel's opinion that Newton was a man of great integrity. Therefore, his religious, socio-political, historical-chronological, alchemical, and physical views should be considered as a whole. Nevertheless, on page 31 of Manuel's book, the author emphasized that *God* was mentioned only once in the first edition of Newton's most famous work, *Principia*!

This and subsequent pages aim to demonstrate that Newtonian celestial mechanics, as a theory, encompasses numerous internal components that are often overlooked by philosophers of science who attempt to portray science and its history comprehensively and accurately.

Qualities of bodies are examples of body attributes postulated by Newton. "For the qualities of bodies can be known only through experiments; therefore, qualities that square with experiments universally are to be regarded as universal qualities, and qualities that cannot be diminished cannot be taken away from bodies. Certainly, idle fancies ought not to be fabricated recklessly against the evidence of experiments, nor should we depart from the analogy of nature since nature is always simple and ever consonant with itself. The extension of bodies is known to us only through our senses, and yet there are bodies beyond the range of these senses. Still, because the extension is found in all sensible bodies, it is ascribed to all bodies universally… And this is the foundation of all natural philosophy. Further, from phenomena, we know that the divided, contiguous parts of bodies can be separated from one another, and from mathematics it is certain that the undivided parts can be distinguished into smaller parts by our reason… Finally, if it is universally established by experiments and astronomical observations that all bodies on or near the earth gravitate (*lit*. are heavy) toward the earth, and do so in proportion to the quantity of matter in each body, and that the moon gravitates (is heavy) toward the earth in proportion to the quantity of its matter…"[17].

Based on centuries-old data from astronomical observations and measurements, Newton identifies phenomena in the domain of mechanics that can be explained by it. Note that this domain includes ascertaining the nonspecific existence of bodies and phenomena generated by them and the quantitative (mathematical) characteristics of these phenomena obtained from observations and measurements. We emphasize that when describing these phenomena, not only the words of the everyday language are used (Sun, Mercury, star, rotation, etc.), but also the terms of Euclidean and Cartesian geometry (center, ellipse, radius, area, etc.), as well as arithmetic (proportion, semicubic ratio, etc.). Here is a description of some of these phenomena, as described by Newton himself.

"Phenomenon 1. *The circumjovial planets (or satellites of Jupiter), by radii drawn to the center of Jupiter, describe areas proportional to the times, and their periodic times – the fixed stars being at rest – are as the 3/2 powers of their distances from that cente.*"[18]

"Phenomenon 2. *The circumsaturnian planets (or satellites of Saturn), by radii drawn to the center of Saturn, describe areas proportional to the times, and their periodic times – the fixed stars being at rest – are as the 3/2 powers of their distances from that cente.*"[19].

"Phenomenon 3. *The orbits of the five primary planets – Mercury, Venus, Mars, Jupiter, and Saturn – encircle the sun*"[20].

"Phenomenon 4. *The periodic times of the five primary planets and of either the sun about the earth or the earth about the sun – the fixed stars being at rest – are as the 3/2 powers of their mean distances from the sun*"[21].

[16] In the same way, many (not all Soviet philosophers) believed in the postulates of Marxist-Leninist philosophy, just as today, many modern philosophers and historians of science are uncritical (although sometimes insincere) adherents of Kuhn's notions of science and its development.

[17] Newton, 1999. P. 441–442.

[18] Ibid. P. 443.

[19] Ibid. P. 444.

[20] Ibid. P. 445.

[21] Ibid. P. 446.

"Phenomenon 5. *The primary planets, by radii drawn to the earth, describe areas in no way proportional to the times but, by radii drawn to the sun, traverse areas proportional to the times*"[22].

"Phenomenon 6. *The moon, by a radius drawn to the center of the earth, describes areas proportional to the times*"[23].

Thus, we have a set of astronomical phenomena explained by Newtonian mechanics.

The first section, "Definitions" of Newton's book[24], begins by introducing the names and definitions of its main elements, which are interpreted with the help of other names and linguistic expressions. Their number includes terms used to define mass (quantity of matter), mechanical motion, force and its various forms, acceleration, quantity of motion, and more. Ideas about space, place, time, and movement are considered and defined separately. Even the great Newton does not distinguish between abstractions and corresponding objects in nature. This is why it is so difficult to formalize and axiomatize physics. Hence, this attempt, as well as all subsequent ones in mechanics, thermodynamics, and electrodynamics, essentially failed. Nevertheless, they all stimulated our understanding of Nature and should be considered valuable actions.

Further, in Section "Axioms, or the Laws of Motion," Newton formulated the basic laws of mechanics, which in their verbal formulation look as follows.

"Law 1. Every body perseveres in its state of being at rest or of moving uniformly straightforward except insofar as it is compelled to change its state by forces impressed"[25].

"Law 2. A change in motion is proportional to the motive force impressed and takes place along the straight line in which that force is impressed."[26].

"Law 3. To any action there is always an opposite and equal reaction; in other words, the actions of two bodies upon each other are always equal and always opposite in direction."[27].

Newton proposed the ontic hypothesis regarding the universal law of gravitation between all bodies in the universe to make these laws applicable to the observed motions of planets. This contradicted Descartes's previous hypothesis that all interactions between material entities have a short-range nature. Some of Newton's contemporaries even accused him of mysticism for this reason. Nevertheless, Newton made his bold choice, which worked well for centuries.

It is necessary to use proper languages to unfold the mechanical laws into a grand closed system. Newton extensively used his unparalleled geometric intuition, based on his knowledge of Euclid's geometry (for a modern scientist, Newton's geometrical reasoning can sometimes be difficult to follow), as well as other specialized scientific languages. Among them, the differential and integral calculus languages, created by both Newton and the German philosopher and naturalist Gottfried Leibniz, still occupy a prominent place in the natural sciences. However, this is certainly not enough. It is also necessary to have symbolic means of presenting system elements and to establish their connections with the names and components of the mathematical knowledge systems used. After that, one can formulate the consequences of axioms, that is, derive the laws of mechanics and apply them to solve actual, practical problems.

The next Section, "The Motion of Bodies," starts with "The method of first and ultimate ratios, for use in demonstrating what follows"[28]. In this Section, methods appear as elements of the system of mechanical knowledge. Some other techniques can be found elsewhere in the treatise. Section "Rules of the Study of Natural Philosophy"[29] contains methodology in

[22] Newton, 1999. P. 447.
[23] Ibid. P. 447.
[24] Ibid. P. 49.
[25] Ibid. P. 62.
[26] Ibid. P. 62.
[27] Ibid. P. 63.
[28] Ibid. P. 79.
[29] Ibid. P. 440.

its pure form. It is a sort of philosophy but is not at all a sort of logic. This is not surprising because new knowledge cannot be reduced by reproducing the previously known works of respected scholars. Unfortunately, this quite natural conclusion is very often neglected in pedagogical activity.

There are many problems with homework in Newton's book. Some of them were formulated and solved by his predecessors, the solutions of others belong to him, the third ones were both proposed and solved by him, and he only formulated the fourth ones. Moreover, entire sections of his work are named according to the methods of solving specific problems. Examples of such titles are "to find centripetal forces"[30] "to find orbits when neither focus is given"[31], "to find motions in given orbits"[32], etc. At the same time, some propositions of his treatise are named theorems, whereas others are called problems. It seems symptomatic that Newton's *Opus Magnum,* to some extent, follows the components of the Old Testament (in particular, the solemn style), although the author himself apparently tried to follow Euclid.

Abovementioned Newton's negative statements about the method of hypotheses are widely known and often misinterpreted. For instance, the most famous one deserves to be cited. "I have not as yet been able to deduce from phenomena the reason for these properties of gravity, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this experimental philosophy, propositions are deduced from the phenomena and are made general by induction"[33].

According to Newton's clearly expressed belief, only those statements about phenomena confirmed by their experimental research (true in this system of knowledge) should be included in the theory and thus in science as a whole. Despite this, even in *Principia*, his most complete work in form and style, not to mention the book *Opticks*[34]*, the reader can easily find many experimentally unproven hypotheses. The controversial and fruitful hypothesis about the corpuscular nature of light is one of them. He puts forward many hypotheses about space and time, asserting that space is absolute and unchanging and time is uniform (knowing well that those are hypotheses!). Evaluating the cautious attitude of the great scientist toward the production of hypotheses, we can confidently state that this concerns redundant (under certain specific conditions) or premature hypotheses, which one can easily avoid. Here, it is worth recalling the reasoning of his compatriot, the philosopher William Ockham, about the razor that should cut off optional entities.*

However, even for the basic laws or axioms of mechanics, which were included in a genre of Newton's "codex," it is more appropriate to classify them as hypotheses that are confirmed in nature or experiment only under certain conditions. Indeed, as was established in the twentieth century, these hypotheses are valid only in the case of macroscopic processes commensurate with the characteristic dimensions of a human. They are not fulfilled both in the micro-world of elementary particles and in the Universe as a whole.

Principia also contains many assessments. In mechanics, such assessments as the probability of causes and their sufficiency to explain phenomena are applied. Statements can be absolutely or approximately true.

The revolutionary contribution to science, summarized in *Principia*, is associated with introducing a large class of mechanical models into science, which proved fruitful even outside mechanics. For example, solid bodies are considered systems of material points in rigid body mechanics. Trajectories of separate material points are modelled as curves in the

[30] Newton, 1999. P. 90.
[31] Ibid. P. 126.
[32] Ibid. P. 156.
[33] Ibid. P. 589.
[34] Newton I. Opticks; Or, A Treatise of the Reflections, Refractions, Inflexions and Colours of Light. New York: Dover Publications, 1952. 406 p.

three-dimensional Euclidean space. Differential equations of motion of mechanical systems are formulated based on suitable mathematical models.

More than three centuries have passed since *Principia* was published. During this time, a number of physical theories of a general and specific kind were proposed. However, they all turned out to be structurally similar to celestial mechanics (which leaves enough possibilities for authors' creativity in the concrete presentations of theories, as we have indicated above). Of course, the specificity of the domains of these theories was reflected in their apparatus, the degree of abstractness of their linguistic means, characteristics of models of the studied phenomena, formulated and solved problems, proposed methods, and assessments. Nevertheless, *in gross*, the architecture of these theories is the same. They differ only in the degree of manifestation, development, and content of their components. For example, in all physical theories, *models* remain *models*, and *attributes* remain *attributes*, but we are talking about *different models* and different *attributes* of *various* entities studied by these theories.

It is essential to recall that the original Newtonian mechanics includes (after expressing some reservations) basic notions of absolute space, absolute time, and action at a distance as the representations of the existing physical entities. Of course, the foresighted scientist put those cornerstones into his world picture not because he did not see the weakness of the proposed notions. However, he needed the adoption of such unproven notions because they were necessary components of the self-contained theoretical construction that described the observations and experimental results well enough (it dominated for several centuries!). The critical analysis became well-timed only in the second half of the 19th century and was carried out by Ernst Mach[35]. His physical and philosophical approach influenced Albert Einstein's reforms of all three notions.

As a result, in the particular theory of relativity, the notions of linked space and time appeared so that their absolute character inherent in Newton's physics was understood as approximate. Furthermore, the nature of the approximation made by Newton only then became apparent. We emphasize that the physical development summarized in the special theory of relativity altered the interpretation of Newtonian notions of space and time. Moreover, the general theory of relativity is a field theory. It acknowledges the dependence of the space-time metrics on the gravitational field and elucidates the essence of the long-range action of classical celestial mechanics. It is worth mentioning that Newton himself recognized the problem from the very beginning of his *Opus Magnum*, as is well known from his correspondence with the Reverend Richard Bentley[36]. To summarize, the emergence of new more powerful theories of mechanical bodies moving in space and time, influenced by the universal gravitational field, altered the initial notions of the basic Newtonian theory, rendering them no longer *ad hoc*.

Our conclusion, based on the history of classical mechanics, is more general. For instance, if one examines Daniel Bernoulli's kinetic atomic theory[37] in the context of modern statistical mechanics developed in the twentieth century, it becomes clear that only then did his notions of atoms acquire sufficient depth.

Considered from a "bird's-eye view," specific physical knowledge systems reveal a much larger number of structural elements than is assumed by each of their interpretations known from the literature. All these elements form different, specially arranged subsystems of any sufficiently mature and developed theory. Note that most methodologists pay attention only to the deductive ordering of such elements as "statements." However, the rest of the subsystems of the physical knowledge system also demonstrate their types of orderliness.

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[35] Mach E. The Science of Mechanics. A Critical and Historical Account of Its Development. 4th ed. Chicago: The Open Court Publishing Company, 1919. 605 p.

[36] Newton I. Letter 1 to Richard Bentley / Ed. A. Janiak. I. *Newton, Philosophical Writings*. Cambridge: Cambridge University Press, 2004. P. 94–96.

[37] Bernoulli D., Bernoulli J. Hydrodynamics and Hydraulics. New York: Dover, 1968. 473 p.

The componential nature of theories should not be surprising since nature itself is componential, as all science textbooks report, although this fact is only sometimes emphasized. At the same time, it should be noted[38] that (i) the components are dynamic, based on the "trembling" ("restless" because the W. Heisenberg uncertainty principle works) nature of microscopic objects, both in non-relativistic quantum mechanics and in quantum field theory, and (ii) contain structural components of different scales. In condensed matter and living organisms, inhomogeneous components can be fractal or hierarchical, and biological systems mainly possess a second type of component. Our meta-theoretical hypothesis is that any real theory contains the necessary types of components listed above.

From a polysystemic perspective, the available philosophical reconstructions of classical mechanics provide partial representations, one common feature of which is the emphasis on the static aspects of this theory. All this does not prevent their authors from posing and solving interesting problems. They involved a comparison between different formulations of these theories[39]. At the same time, polysystemic reconstruction highlights the universal and necessary components of practical physical theories, allowing them to be examined as variable and interrelated.

We note that the treatment of theories as a system of interconnected components presented here is not at all trivial. Indeed, in many publications on the subject, a theory is understood as a model or a collection of recipes dictating the necessary way to carry out specific research. Such a narrowing of the term prevents philosophers of science from creating the scientific "theory of theories", which is needed to see the ideological and structural closeness among various practical theories grounded in Newton's views outlined in the *Principia*, as we explicitly explain here.

Basic system-forming components of practical scientific theories. There are many valuable sources devoted to the historical-cultural conditions[40], perception[41], and contemporary understanding[42] of *Principia*. We limited ourselves only to componential aspects of this evergreen intellectual monument, which seem to be more or less evident but, as a rule, are neglected by physicists and philosophers of physics. Our brief examination of Newtonian *Principia* has shown that there are good and verifiable reasons for distinguishing between various types of components in any specific theory. Note that some philosophers and physicists

[38] Hendry R. F. Structure, scale and emergence. *Studies in History and Philosophy of Science.* 2021. Vol. 85. P. 44–53. https://doi.org/10.1016/j.shpsa.2020.08.006.

[39] Barrett T. W. On the structure of classical mechanics. *The British Journal for the Philosophy of Science*. 2015. Vol. 66. № 4. P. 801–828. https://doi.org/10.1093/bjps/axu005; Barrett T. W. Equivalent and inequivalent formulations of classical mechanics. *The British Journal for the Philosophy of Science*. 2019. Vol. 70. № 4. P. 1167–1199. https://doi.org 10.1093/bjps/axy017; Curiel E. Classical mechanics is Lagrangian. It is not Hamiltonian. *The British Journal for the Philosophy of Science*. 2013. Vol. 65. № 2. P. 269–321. https://doi.org/10.1093/bjps/axs034; Hunt J., Carcassi G., Aidala C. Hamiltonian privilege. *Erkenntnis.* 2023. Vol. 90. P. 443–466. https://doi.org/10.1007/s10670–023–00708–0; Janiak A., Schliesser E. (eds). Interpreting Newton. Critical Essays. Cambridge: Cambridge University Press, 2012. 441 p.; North J. Formulations of classical mechanics. / Eds. E. Knox, A. Wilson (eds). *A Companion to the Philosophy of Physics*. New York: Routledge. 2022. P. 21–32.; Tuynman G. M. The Hamiltonian? / Eds. P. Kielanowski, P. Bieliavsky, A. Odesskii, A. Odzijewicz, M. Schlichenmaier, T. Voronov. *Geometric Methods in Physics. Trends in Mathematics.* Cham: Birkhäuser, 2014. P. 287–290.

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prefer to consider these components as concepts[43]. From this perspective, the components highlighted in this article demonstrate the range of concepts within a specific theory. As separate and disconnected structures of scientific cognition, almost all these components were and are subjects of classical and modern studies. The lines below, together with the names of the theory's components, contain some references to works devoted to studying them.

Entering the theory, these structures became its interrelated components and obtained new qualities. For example, at a certain moment, in theory, only models that can be constructed with the available languages are permitted. Introducing a new language opens the possibility of constructing new models. This occurred when quantum theoreticians began to use operational language instead of functional language for modelling the attributes of micro-entities. New models open avenues to set new problems, which, in turn, need to be resolved by available and new methods.

Thus, the obligatory types of any specific theory's components are:

– ideas of the objective existence of external real entities and their attributes, studied within the theory's framework[44];

– common ordinary names, symbols, notations, and informal descriptions not only of entities and their attributes but also of their models, as well as problems with their explanation, calculation of the values of their attributes, etc.[45]; – implicit and explicit definitions[46];

– ordinary, mathematical, universal physical, and theory-specific languages[47];

– substantive and mathematical models of theory's entities and their attributes[48];

– laws for entities and their attributes[49];

– approximations used in theory[50];

– solved and unsolved internal and empirical theories' (intra- and external) problems[51];

– various operations with theory's components[52];

[43] Rolleri J. L. A conceptualist survey of physical theories. *Philosophy Study.* 2023. Vol. 13. № 11. P. 482–495 doi: 10.17265/2159-5313/2023.11.004.

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– procedures as rules for performing operations[53];
– research methods as sequences of operations subject to procedures[54];
– internal and external evaluations of theory's components[55];
– heuristics[56];
– hypotheses[57];
– means of logical, model, problem etc. orderings[58];
– links between the theory's elements[59];

Conclusion. All types of components identified above reflect the polysystemic nature of celestial mechanics and theories that emerged in its image and likeness[60]. Whatever the specifics of micro- or mega-scale objects of the Universe, their theories have architectonics like the polysystemic composition of celestial mechanics. At the same time, theories differ in content depending on the entities being studied and the experimental conditions under which they are explored.

The theoretical description of the physical world is not complete and final now, as it was not in the past and will not be in the future. It is only an approximation to reality. The world is what our changeable and experimentally tested physical theories state about it. All components of theories play a pivotal role in the evolution of our physical picture. It is not enough to be restricted by models of entities studied experimentally alone.

To reach the proper physical and philosophical understanding of the theoretically based world picture created by the most outstanding personalities in human history, it is necessary to catalogize components of the physical knowledge systems and their highest forms – theories in full detail and scale. Otherwise, the philosopher is in danger of accepting pre-physical, nonphysical, and even anti-physical ideas about science, its theories, and its history. To avoid this situation, one should learn "how one thing leads to another"[61].

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ТЕОРЕТИЧНІ ОСОБЛИВОСТІ ІСТОРИЧНО-АНТРОПОЛОГІЧНОЇ ВЕРСІЇ СУЧАСНОЇ ФІЛОСОФІЇ ІСТОРІЇ

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Анотація. Метою роботи є виокремлення й розкриття змісту теоретичних особливостей історично-антропологічної версії сучасної філософії історії в горизонті осмислення нею ментально-культурної площини минулого, каузальності, сутності й альтернатив розвитку історичної динаміки. **Методологія** цієї праці засновується на принципах комплементарності, структурності, діалогічності і методах філософської герменевтики, системно-структурному й міждисциплінарному. **Результати дослідження**. Історична антропологія як версія сучасної філософії історії почала утворюватися в першій третині ХХ ст. у контексті низки важливих соціально-історичних, соціально-культурних і теоретико-методологічних причин. Теоретичні особливості історично-антропологічних розвідок формувалися на розумовій підставі надбань низки розгалужень філософської й соціально-гуманітарної думки, філософської антропології, філософії історії, філософії структуралізму і постструктуралізму, теорій соціології й етнології. У ході інтелектуально-пізнавального розвитку історичної антропології як версії сучасної філософії історії утворилася засаднича для неї система понять і категорій, онтологічних (елементи проблемного поля та їх зміст), методологічних (пізнавальні методи) й аксіологічних (система цінностей і ідеалів). Сукупність властивих історично-антропологічному горизонту сучасної філософії історії теоретичних основ, понять і категорій, методів дослідження, проблемного поля, ментально-культурної площини історичних процесів, визначають його оригінальність стосовно інших парадигм філософії історії ХХ – початку ХХІ ст., лінеарних, циклічних, теорії «осьового часу» К. Ясперса. Оригінальність історично-антропологічної версії сучасної філософії історії знаходить прояв в її інноваційно-пізнавальній діяльності, яка має істотне значення для розвитку філософських і соціально-гуманітарних концепцій. Вона реалізується за такими напрямами, як проведення інтенсивного міждисциплінарного діалогу, застосування підходів багатозначної логіки й синергетики для гуманітарної площини різнорівневих історичних