https://doi.org/10.15407/fd2025.04.131
UDC 5:1,001.1

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WHAT COMPONENTS DOES A SPECIFIC SCIENTIFIC THEORY CONSIST OF? (PART 1)

Strong minds discuss ideas, average minds
discuss events, weak minds discuss people.

Socrates

By specific theories, we mean scientific theories that focus on particular types of material reality or phenomena, such as elementary particles, plasma, superconducting materials, quantum tunnelling, chemical reactions, gene regulation, tectonic plate movement, and the Universe.

Citation: Gabovich, O., Kuznetsov, V. (2025). What components does a specific scientific theory consist of? (part 1). *Philosophical Thought*, 4, 131—149. https://doi.org/10.15407/fd2025.04.131

After examining various visions of the theory division into components proposed by some of the prominent scientists (Isaak Newton, James Clerk Maxwell, Heinrich Rudolf Hertz, Pierre Maurice Marie Duhem, Max Karl Ernst Ludwig Planck, Albert Einstein, Norman Robert Campbel, Percy Williams Bridgman, and Gerardus (Gerard) 't Hooft) and philosophers of science (Carl/Karl Raimund Popper, Thomas Samuel Kuhn, Imre Lakatos, Paul Karl Feyerabend, Mario Augusto Bunge, Ronald Nelson Giere, Joseph Donald Sneed, Wolfgang Balzer, and Carlos Ulises Moulines), one finds that these visions fail to consider all essential components and omit many important details, even of the chosen components. Incomplete and undifferentiated visions, on the one hand, overlook many critical features of a theory, including its development and connections with other theories. On the other hand, such visions often generate pseudo-problems, such as the incomparability of classical and quantum theories. As theories underpin the modern sciences, such perspectives lead to oversimplified and overly general understandings of science and its progress. The article briefly emphasizes the significance and utility of the polysystemic vision of specific theories and their development within history, philosophy, sociology, and pedagogy of science. The first part of the article presents the types of components and physicists' views of theories. The second part addresses the views of philosophers and our conclusions. We emphasize that in the first part, we described a bridge between Newton's unfading template of scientific theory and the newest trends in the interpretation of modern physical theories. It is a clear example of the Western scientific tradition of both continuity and change, so that the final product looks different, but its structure remains stable, familiar, and convenient for professionals. That is why it is quite possible for a modern-day scientist to read Newton and find statements useful for his practical activity, not to talk about specific pearls created by the genius.

Keywords: *specific theories; complexity; types of components; polysystemic view; subsystems.*

PART 1

Introduction

> As specialists, we are all inclined to ignore the most obvious questions or to be reticent to state the obvious for fear of being obvious.
>
> *Andrew Pettigrew*

The term "theory" appears in nearly all scientific publications across the natural, social, and humanities sciences. However, the understandings of its referents vary, even within physics. One goal among various philosophies of physics is to clarify the components that comprise specific theories. Regardless of one's stance on this, the state of physical theories influences the rest of the natural sciences (chemistry, biology, geology, astronomy, etc.) as well as social sciences and humanities. It is hard to deny that what is called theories in these sciences often differ markedly from what functions as a theory in physics. The situation is further complicated by the fact that, within physics itself, there is no consensus on how physical theories are structured, what their real cognitive functions are, what their properties as tools of cognition entail, or how different theories relate to one another. The first step in addressing these complex issues is to answer the obvious question: what components actually make up physical theories? Instead of referring to numerous available differing answers to it, we have analyzed (Gabovich, Kuznetsov, 2023a,b; 2025b) the original text of Newtonian celestial mechanics (Newton, 1687/1999). Consequently, we found that it constitutes an archetype of a specific theory originally constructed to describe the motions of celestial bodies.

Do not miss a number of components characterizing a theory

A specific theory encompasses a broader range of component types and subtypes than is usually recognized by authors of various views on the theory composition.

These types and subtypes are:

1) NAMES. We understand names in the sense of the theory of named sets (Burgin, 2011; 2012) and interpret them as something natural, or artificial, material, or ideal, textual or mental that can function as a denotation/indication of other things. Examples of abstract names include designations using symbols, mathematical signs, words, expressions, and texts in both natural and artificial languages (Gelfert, 2011; Kragh, 2024; Pepp, 2019). In a specific scientific theory, abstract names constitute its complex denominative subsystem. Its components are used to denote all other components of the theory and realities from its domain. Suppose a composite reality (such as the Solar system, the atom, and so on) is given a certain name. In that case, some of the complex names of its components include this name, which indicates their belonging to the composite reality (for example, the Earth is a planet of the Solar system, and the electron is part of the atomic shell).

The repertoire of names associated with the specific theory is diverse and typically falls outside the views of both scientists and philosophers on the theory. Meanwhile, an entity without a name does not exist for the researcher. In a sense, we all live in a world of named entities. Although science continues to use common names and sensory images of the entities it studies as scientific denotations, constructed abstract names are becoming increasingly important in it. Some of them, on the one hand, can be processed mathematically (analytically or numerically by a scientist's mind and programmatically on computers) and, on the other hand, can denote entities that are not sensorily given. Ignoring specifics of types and the functions of names as essential parts of the theory leads to equating names with the concepts and realities they designate, as well as equating concepts with the realities they refer to. Celestial bodies have general names, such as planet, satellite, star, comet, and asteroid, as well as singular names, including Earth, Moon, Phobos, Halley's Comet, Sun, 7P/Churyumov-Gerasimenko Comet, and 99942/Apophis. To describe celestial bodies, one also uses complex modelling names such as 'material points' and 'bodies deformed by the influence of other bodies.' Examples of connections between names include links between the names of reality and names of its attributes, as well as between attribute names and the names of their quantitative scales. In turn, to work with these connections, it is necessary to assign the appropriate names to them.

The totality of names used in a certain scientific branch is called a "jargon", i.e. the specialized language. Scientific jargon changes relatively rapidly and continuously, reflecting advances in understanding the depths of science, as is readily seen in chemistry (Rulev, 2025). One should confess that without the scientific jargon, any theory could not develop, although it is always to some extent misleading, as can be seen from the inadequate usage of partially obsolete terms: "wave-particle duality", "reduction of the wave function", "electron orbital".

2) ONTIC PRESUPPOSITIONS. They assert what kind of realities are considered as studied by means of theory and what their attributes are.

Without such typically apodictic existential statements (e.g., there are celestial bodies such as the Sun and the Moon; there are various types of elementary particles), and sometimes hypothetical (strings are considered ultimate microrealities), a theory cannot be termed a specific scientific theory. (Nevertheless, those statements themselves are consequences of the previous development of the relevant scientific branch). For instance, celestial mechanics studies the spatial motion of material celestial bodies, seen by various kinds of telescopes or detected indirectly, under the influence of external forces. At the same time, one observes the Brownian walks of microscopic particles by optical microscopes.

In a specific theory, ontic presuppositions constitute its complex ontic subsystem. It includes not only existential statements about realities within its domain but also such statements about their attributes (properties, relations, states, interactions, processes they participate in, and phenomena they produce), as well as the scales of attribute values. The relevant concretizations are as follows. Planets have mass, which is a measured scalar quantity. Planets in a Solar system are moving in the same plane. Their state of motion is approximately stable and predictable with some degree of accuracy. Their mutual gravitational interactions are much smaller than those with the Sun and, in the first approximation, can be treated by perturbation theory. Planet trajectories observed from the Earth include the so-called retrograde motions.

3) DEFINITIONS. Newton took as evident what celestial bodies are and did not present their exact definition. Assuming hypothetically that they are, by nature, identical to earthly bodies and consequently that their certain attributes (mass, acceleration, and force) are the same as those of earthly bodies, while describing their observed trajectories, he added to his three laws, valid

for the ideal frictionless motion of earthly bodies, the law of gravitation. This approach enabled him to calculate planetary trajectories that, to a certain degree of accuracy, coincided with quantitative data from astronomical observations. Moreover, sometimes he corrected observational data and was right.

In a sense, he employed informal descriptive definitions of celestial bodies that differ from earthly bodies only in the magnitudes of their attribute values. The mass of the Sun is 99.86 of % mass of the Solar system. In turn, the earthly bodies were defined as sensorily heavy bodies, the mass of which is a measure of the substance ("materia") contained within them. The cause of the change in state of moving bodies is attributed to the force exerted by the Sun.

It seems that the role of formal definitions for realities studied by specific theories is somewhat exaggerated. We did not find many definitions in the classical and non-classical physical theories known to us (such as classical electrodynamics and thermodynamics, atomic theories, quantum field theories, elementary particle theories, and superconductivity theories), as they are used in scientific practice. Indeed, such definitions mostly appear in attempts to axiomatize theories such as the axiomatization of classical thermodynamics by C. Carathéodory (1909) and classical particle mechanics by J. C. C. McKinsey, A. C. Sugar, P. Suppes (1953). However, the benefits of these versions of axiomatized theories for deepening and expanding knowledge of realities studied are questionable. It appears that, in the context of triplet terms, the concept of specific theories, like other scientific concepts, is somewhat fuzzy in certain aspects (Kuznetsov, Kuznetsova, 1999) and is not so precisely and unimodally defined as it is supposed by many philosophers of science.

Nevertheless, some formal definitions are essential for constructing mathematical models of the realities under study and their attributes. The reason is the use of mathematical tools, especially precise mathematical equations, for their modelling (Sereni, 2024). In view of that, there is a basis for introducing and studying a definitional subsystem of a specific theory. However, it mostly contains informal or intuitive definitions, not as formal and exact as the logic-focused philosophers of science demand in their analysis of specific scientific theories (Giovannini, Schiemer, 2021).

4) LANGUAGES. When considering specific theories in the context of physical cognition, it becomes apparent that they do not employ a single, undefined mathematical language, but rather a variety of specific languages (more precisely, language fragments) borrowed from different mathematical theories. These are known as languages for special purposes (Kuznetsov, Shataliuk, 2024). There are specific languages for describing all components of theory, such as models, problems, operations, approximations, and assessments. The natural language plays, at least, the role of glue between these languages. By the way, Newtonian celestial mechanics uses the languages of Euclidean geometry, arithmetic, differential and integral calculus. As his thinking was also not in

violation of the laws (*modus ponens* and *modus tollens*) of ordinary reasoning, one can state that he implicitly used the language of informal logic.

5) and 6) REPRESENTATIVE and FORMAL MODELS. Theory comprises representative and formal types of abstract models (Frigg, 2022; Hintikka, 1981, 2007). They provide, correspondingly, qualitative and quantitative information about the named realities whose existence is presupposed by the ontic subsystem and studied with the help of theory. No practical, specific theory exists without these models. Metaphorically, theory "captures" the realities and related phenomena under study through the lens of its models. A theory without models is helpless and lacks specificity. Furthermore, models, in theory (not models of theory in the sense of mathematical logic), generate an informative vision of realities that other components of theory can implement. Naming realities and their attributes is only the initial and necessary step in their modelling.

Descriptions of representative models (some of which are visual or pictorial) are provided in natural human languages. These encompass general existential information about the attributes and parts of realities, as well as their connections. Such models create essential resources for studying celestial, macroscopic, and microscopic objects in a more formal way. Thus, scientists depict realities in terms of their internal components and attributes (Gabovich, Kuznetsov, 2022).

Formal, professional models are constructed using, in particular, mathematical languages that enable the calculation of countable quantities (scalar, vector, tensor, spinor, etc.) intended to adequately describe attributes of reality (Burgin, Kuznetsov, 1993a).

Newton depicted the Solar system as consisting of a set of massive planets that rotate along elliptical trajectories around the Sun, which is the source of gravitation that keeps the planets together. Following his eternal template, any specific theory examines realities whose existence is postulated in its ontic subsystem through a prism of representative models that characterize each theory. By the way, models constructed in one theory are successfully used in other theories. For instance, models of classical or quantum oscillators, which were inspired by observations of the ancient pendulum, are used throughout physics and other natural and social sciences. In particular, the Fock's representation of quantum electrodynamics treats the electromagnetic field as an infinite set of photons, each treated as a quantum oscillator (Fock, 1978).

Bearing in mind good old Newton's model of the Solar system, scientists have represented hadrons (a class of elementary particles that participate in the fundamental strong interactions) as composed of sub-elementary entities. However, the analogy is far from being complete, since in this case the binding energy is comparable to the energy associated with the component masses, so that the term "made up" becomes a trap connected to the inadequacy of ordinary language.

It is important to note that in Newton's original theory, planets were assumed to move in the empty space of Democritus, although Newton himself already understood the weakness of the long-range-force concept. The problem was solved only in Einstein's general relativity theory. On the other hand, the world of elementary particles is not classical; in principle, it is full of virtual objects that emerge and disappear in the vacuum, which is no longer empty space but a complex realm of quantum objects with numerous attributes (Berezhnoi, 2005).

The indicated representative models do not provide detailed quantitative predictions of planetary trajectories that match astronomical observational data, nor do they predict the types and numerical values of attributes of hadron interaction products created in colliders. Currently, no real scientist or even philosopher doubts the objective existence of planets and the Sun. However, some philosophers question the objective, independent existence of micro-objects (elementary quanta are also considered micro-objects), regardless of the acts of observation during experimental studies. This issue should be examined within the context of quantum field theory and the experimental tools used in physics. Through a long and successful process of experimental verification, physicists now regard quark models as the most accurate representations of hadron composition and tentatively accept that hadrons are what their quark models suggest they are. Indeed, in the 1960s, the dominant physical view was that quarks were merely abstract models of constituents of hadrons, but today quarks (and gluons) are almost universally regarded by physicists as the true material constituents of particles. The primary difference between models of planets and models of particles lies in the relative perceptibility of planets by the senses, with particles being less perceptible than planets (Wood, Sherman, 2022).

7) PROBLEMS.

Models do not exist as a self-contained part of the theory. The aim of their formulation is to create tools to solve problems in the natural sciences, and after World War II, these tools were frequently applied to the social sciences as well. It is correct to state that models are invented to formulate and solve problems; in other words, problems stimulate the creation of models. In their turn, models generated to solve certain problems are subsequently used to solve other problems more or less related to the initial problem. Sometimes, the problems themselves are formulated after the suitable models emerge. For instance, after the Bardeen-Cooper-Schrieffer model of metal superconductivity was suggested, it was applied to the proposed superfluidity of liquid ^{3}He (Annett, 2004). Without such a model, nobody guessed that helium three was a superfluid based on the Cooper pairing.

However, there are many other ways for theoretical problems to occur. It would not be an exaggeration to say that theories serve as a complex means of resolving contradictions and solving problems that nonscientific minds are unable to resolve. Mature theories are stimulators of the posing of new problems. Internal problems aim to resolve inconsistencies in theory, while external problems seek to find solutions to contradictions contained in the whole body of experimental data (Gabovich, Kuznetsov, 2016).

Thus, a theory that neither poses nor resolves new problems is, at best, the carrier of old problems and their solutions. Its potential becomes evident and attractive for new generations of scientists through its fruitful expansion into a new realm. Celestial mechanics was the starter and basis of classical physics. Planck's quantum theory of radiation plays a similar role in quantum physics.

Considering scientific questions as a form of presentation of problems in theory (Burgin, Kuznetsov, 1986b), in a sense, "the point of a scientific theory is to establish a framework which takes into account as many (empirical) questions as possible. The price which has to be paid is the creation of theoretical structures—in this case theoretical questions (because they are not empirical or black-boxed)—which are one step further removed from the world than empirical questions. The balance or trade-off between these two kinds of questions defines how well a theory has added to our understanding and to what extent there has been a gain which makes the enterprise worthwhile" (Sanitt, 2007: p. 442).

8) and 9). OPERATIONS and PROCEDURES. Problems should be solved through the efforts of theoreticians, and their solutions do not appear as *deus ex machina*. To accomplish this, theoreticians should devise a creative sequence of operations that leads to the correct resolution. Sometimes, great scientists arrive at a solution instantly, immediately after formulating the problem. Others spend considerable time and mental effort on the problem-solving process.

Anyway, operations are not arbitrary but are subsumed under procedures or rules of their realization in a specific theory. For example, without the careful use of procedures for fulfilling operations with infinite series, any reasoning that uses infinite series is good for nothing and should be rejected (see ten Berge, van Hezewijk, 1999). There are nontrivial relationships between solving a certain problem and posing new problems. In a sense, scientific methods are intricate and evolving sequences of operations that are effective in solving a certain class of scientific problems. Operations themselves are not arbitrary and are guided by appropriate procedures (compare with Gimbel, 2011). The totality of operations in a developed branch of science constitutes the scientific protocol (Gabovich, Kuznetsov, Voitenko, 2025). The latter is obligatory, for example, in practical medical applications.

10) NOMIC STRUCTURES. Old and new models should not contradict the theory's laws, which mimic the laws of nature (Chen, 2024; Halpin, 2003). For example, a model violating the law of energy conservation will be automatically excluded from scientific consideration in most areas of research (not in dark energy theories, where the situation is more intricate (Josset et al., 2017)).

It should also be emphasized that in general relativity, the energy-momentum conservation law is "only" a local one but is extremely important, similarly to other physical theories (Rindler, 2006; Schutz, 2009).

As noted above, in a specific theory, problems are posed in the language dictated by the models, and their resolution is achieved through procedurally allowed operations according to the theory's laws. Although many laws of theories take the form of various mathematical equations, contemporary theories encompass forms beyond this. These include principles of symmetry, in Eugene Wigner's terminology, laws of laws (Wigner, 1964) or the laws of second order, supersymmetry laws (laws of higher orders) (Бургин, Кузнецов, 1986a), and tendencies (Бургин, Кузнецов, 1993). Additionally, during the development and application of theory, the rules and procedures governing the construction and modification of its components play a role analogous to the laws of the realities under study. All these structures are interconnected elements of the nomic subsystem of the theory, which is in the early stages of its philosophical examination.

11) HYPOTHESES. Any theory depends on presuppositions that, at the time they are proposed, lack sufficient evidence to be considered true, fully explained, or dismissed from the outset. In this sense, they are more or less plausible hypotheses accepted as true because they assist in explaining the phenomena being studied. An example is Newton's assertion of the universality of his law of gravitation. In principle, even the conservation laws are, in a sense, hypotheses that conflict with the hypothesis of the Big Bang (Grünbaum, 1989). The primary reason these laws are regarded as true without question is that, so far, their consequences have been confirmed by all experiments conducted. The second is that their violation would fundamentally undermine the current understanding of physics. Upon close examination, it becomes clear that such hypotheses are interconnected and constitute part of a hypothetical subsystem within a theory. For instance, according to the renowned Noether's theorem, the hypothesis of energy conservation is a consequence of the hypothesis of spatial uniformity (see also Dethier, 2019).

12) LOGISTICAL STRUCTURES. Considering logic in a broad sense as a system of rules which one cannot violate during thinking and textual exposition of its outcomes, one can find several logistical kinds of producing and organizing theories. The most popular is its hypothetical-deductive variant. The lesser-known version is that which begins with the formulation of a very general problem that describes physical reality and its subsequent concretization for a chosen particular kind of reality and associated phenomena. To some extent, this realization was attempted in the exposition of philosophy by posing and answering the so-called most important and general question, such as what is primary: matter or consciousness, being or nonbeing? The latter version was realized in the well-known textbook of theoretical physics by Lev Landau and

Evgenii Lifshitz. Roughly speaking, in every scientific branch (textbook volume), they started from the variational principles, totally neglecting the historical aspect of physics. There are other kinds of theory organization. They are elements of the logistical subsystem of a theory.

13) EVALUATIONS. Many evaluations are linked to a theory as a whole unit. Some of them assess it as being scientific, empirical, axiomatized, grounded, accepted, paradigmatic, original, perspectival, fundamental, and innovative. There are also many evaluations embedded within a theory that are used to assess its components. Names are evaluated as formal, complex, and symbolic, while models are viewed as heuristic, experimentally confirmed, and aesthetically pleasing (Burgin, Kuznetsov, 1993a), with problems being considered as actual, challenging, and unresolved. Embedded evaluations become increasingly important and prominent as the process of exploring ways to develop the theory internally and apply it to new experimental situations unfolds (Burgin, Kuznetsov, 1993c; Gabovich, Kuznetsov, 2025a,b).

14) HEURISTIC MEANS. They are a form of evaluation that highlights the components effective in fulfilling their functions, but they are not sufficiently grounded in certain aspects. Newton's Law of Universal Gravitation was and remains one of the most significant laws in the history of physics. However, even much later, in Faraday's time, the concept of the continuous physical field was considered as a competitor to gravitation. Only the birth of the general relativity theory showed that both viewpoints are valid and even related.

15) APPROXIMATIONS. Any specific theory describes realities within its domain only approximately, with a certain degree of precision. There are many reasons for a theory's approximate nature (Decock, Douven, Kelp, Wenmackers, 2014). The simplified model is clearer and easier to understand. In fact, a model is inherently only a partial representation of the realities it aims to depict. It is based on attributes that are considered fundamental under specific experimental conditions. In the past, the realities studied by atomic-molecular theories were seen as structureless because there were no experimental tools to explore their internal composition. From the nineteenth century onwards, such tools have been developed, allowing the investigation of many properties of atoms as structured microscopic realities. There is also the aspect of operational imprecision in theory, mainly because any real problem, firstly, does not have a perfectly exact solution, and secondly, its experimental validation always involves some degree of inaccuracy.

16) COUPLING BETWEEN COMPONENTS. Many examples of connections between components of a theory have been presented above. This is only a small part of the elements connecting subsystems of a theory. Without these connections, a theory would resemble a random assembly of components, each of which would be impossible to accept, trust, develop, apply, confirm, or refute separately. The implementation of the functions required by a theory is

only feasible when its components are sufficiently developed and can operate interdependently as networks.

Thus, we suppose that a specific theory contains many more types of components than any other vision of a theory suggests. Taking this meta-theoretical hypothesis as a reference frame, we will scrutinize some influential componential visions of theories.

The article explores various common scientific and philosophical perspectives on what constitutes a physical theory, regardless of how different authors interpret its components. For a discussion of these interpretations, readers can consult Roman Frigg's book (2022). This monograph offers excellent examples of how different authors often associate the same term with vastly different referents.

Answers from theoretical physicists

Some prominent physicists directly responded to the question under consideration. Usually, their answers were short remarks for laymen about what the theory was or paragraphs from their professional articles. It is a pity that in most cases their lucid answers were not transformed into specific studies of the theory's composition.

As far as we know, Heinrich Hertz was the first to indicate the major components of a theory directly. According to his famous and somewhat intentionally incomplete answer to the question, "What is Maxwell's theory?" he gave a short and definite answer: "Maxwell's theory is Maxwell's system of equations" (Hertz, 1893: p. 21). Surely, this statement must be taken with *cum grano salis*, as the equations to be a component of a specific physical theory ought to be added by methods of their solution, and, even more, solutions should be compared with experimental data. Actually, Maxwell's equations summarized theories elaborated by his wise predecessors and contemporaries and were based on great ideas by the experimentalist and natural philosopher Michael Faraday, who formulated the electric and magnetic field theory without mathematics but using his famous "lines of force" (Tweney, 2009; Whetham, 1905).

Pointing out the last factor, Albert Einstein asserted that a theory consists schematically of a system of axioms/laws and deduced statements about experimental data (in his words: about "variety of immediate experiences (of the senses)"). (Einstein, 1952/2011: p. 114)) However, in his very influential co-authored article, one can find the statement that any theory consists of concepts "with which the theory operates. These concepts are intended to correspond with the objective reality, and by means of these concepts, we picture this reality to ourselves" (Einstein, Rosen, Podolsky, 1935: p. 777). Thus, a theory consists of concepts, axioms, deduction rules, statements about data, operations with them, and the ways (correspondence rules) of establishing connections between concepts and entities they represent. All these components, including operations with other concepts, are named as concepts. In a sense, operations are concepts of concepts.

In his collection of professional and popular works (Einstein, 2024), the word "concept" and its near-synonyms (conception, idea, and notion) are referenced more than a thousand times. Yet, despite their frequent use, Einstein does not clarify what he means by them.

The contemporary physicist Gerard ʻt Hooft followed Einstein and replaced axioms with equations, considering only the operations of solving these equations. The question of whether such operations can be reduced to purely logical actions of deriving statements from equations remains unclear. He briefly overviews "classical" field theories (James Maxwell's theory of electromagnetism; Isaac Newton's theory of gravitation and Einstein's extension of it), Erwin Schrödinger's wave mechanics, quantum field theory, theories of weakly coupled elementary particles, renormalizable theories, planar field theory in four dimensions, and quantum gravity theories. All of these contain specific equations. However, to recognize these systems as genuine physical theories, physicists should be able to solve equations under consideration, and the solutions obtained should "predict the behavior of the quantities involved under a wide set of circumstances" ('t Hooft, 1984: p. 129—14). The equations in these theories do not have exact solutions. That means that all practical theories, in principle, give only an approximate picture of phenomena from their domain.

To the authors' knowledge, Pierre Duhem was the first philosophically minded professional physicist who devoted a book to physical theories. Accentuating the use of mathematics in theories, he asserted that symbols are theory components. In his view, they denote only realities and their attributes, which are external to the theory. There is no inherent connection between the symbol and the reality it represents. Symbols are parts of a system where they do not serve as the main element, as the relationships between them do. Symbols are selected for their ease of use (Duhem, 1906).

Max Planck (Planck, 1960) also devoted a book to the analysis of theories. He wrote that a theory resembles a complicated organism, whose separate parts are so intimately connected that any interference in one part must, to some extent, affect other parts of the theory. He mentioned definitions, dynamical, statistical, and conservation laws, the principle of least action, conceptions of physical quantities and their quantitative values, space, time, motion, energy, processes, irreversibility, entropy, action, heat, disorder, order, oscillations, and the like. This means that he implicitly admitted that concepts are different in kind.

A physicist, Norman Robert Campbell, considered theories to be a necessary, constitutive, and irremovable part of physics. From his statement "theory is defined by means of the formal nature and connection of the propositions of which it consists, namely a hypothesis, making assertions about hypothetical ideas characteristic of the theory, and a dictionary, relating these ideas to the concepts of the laws explained by the theory" (Campbell, 1920: p. 199), one can conclude the following. He emphasized the formal (usage of mathematics and logical/deductive ordering), connective (interrelations between components), and hypothetical (components are not apodictic truths) nature of theories. Such nature is embodied in the theory's propositions and assertions about them. Thus, theory consists of propositions, some of which are ideas and assertions. Ideas are supplemented by a dictionary, which relates them to the concepts explained by the laws in the theory. From this formulation, it follows that components of theory are such concepts as those appropriate to laws as well as laws themselves.

Summarizing and partially explicating his understanding of the theory given in the previous citation, Campbell wrote: "...a theory is a connected set of propositions which are divided into two groups. One group consists of statements about some collection of ideas which are characteristic of the theory; the other group consists of statements of the relation between these ideas and some other ideas of a different nature. The first group will be termed collectively the 'hypothesis' of the theory; the second group the 'dictionary'. The hypothesis is so called, in accordance with the sense that has just been stated, because the propositions composing it are incapable of proof or of disproof by themselves; they must be significant, but, taken apart from the dictionary, they appear arbitrary assumptions. They may be considered accordingly as providing a 'definition by postulate' of the ideas which are characteristic of the hypothesis. The ideas which are related by means of the dictionary to the ideas of the hypothesis are, on the other hand, such that something is known about them apart from the theory. It must be possible to determine, apart from all knowledge of the theory, whether certain propositions involving these ideas are true or false. The dictionary relates some of these propositions of which the truth or falsity is known to certain propositions involving the hypothetical ideas by stating that if the first set of propositions is true then the second set is true and vice versa; this relation may be expressed by the statement that the first set implies the second" (Campbell, 1920: p. 122). From this passage, it appears that the definitions and postulates are also components of a theory.

We considered some details of Campbell's view because, unlike many other physicists, he provided a somewhat fuzzy but intuitively clear perspective on the theory's components and demonstrated their presence in particular theories (the dynamical theory of gases, Fourier's theory of heat conduction, Maxwell's theory, and theory of gravitation).

The specialist in high-pressure physics and disseminator of dimensional analysis, Percy Bridgman, also wrote a book about theories. He stated that «any theory is what it actually does, not what it says it does or what its author thinks it does, for these are often very different things indeed» (Bridgman, 1936; p. 5). From this, one can conclude that operations are the theory's components.

In the spirit of Bridgman, J. Hintikka (1981, 2007), N. Jardine (2000), and N. Sanitt view science as an interrogative process, and N. Sanitt also models a theory from a graph-theoretical perspective. This makes it possible to represent theory "as a network of questions and answers" (Sanitt, 1996: p. 39). This author is one of the few physicists who not only are informed about the content of concrete theories but also explicitly build their models.

The editors of many professional physical reference books, handbooks, dictionaries, and encyclopedias prefer not to include pages, paragraphs and articles directly devoted to the theory as such (Alenitsyn, Butikov, Kondratyev, 1997; Basu, 2001; Benenson, Harris, Stöcker, Lutz, 2002; Chapple, 1999; Fischer-Cripps, 2015; Flügge, 1956-1984; Françoise, Naber, Tsun, 2006; Kirkby, 2011; Lerner, Trigg, 1991; Parker, 1993; Rigden, 1996; Szabo, Bojowald, 2025). Such sources do not provide even a tentative list of theory components. While they do offer a concise exposition of numerous specific theories, they provide no insight into the universal composition and attributes of a theory, or, philosophically speaking, a concept of theories.

Even when contemporary physicists explain what they understand under a theory, they accentuate its holistic attributes (elegance, efficiency, mathematical languages used, support by experimental evidence, et cetera) and functions (explanations and predictions of facts, calculation of attribute values of studied realities) and miss the description of its composition (Knight, 1989: p. 234—235).

Several contemporary theoretical and applied physicists express their valuable opinions about the components of theories in professional articles. In view of L. Ratner (2003: p. 73), components (in the author's words, features) of the theory are a mathematical description, a logical structure, physical concepts, methods of verification of the theory, and a method of establishing the domain of the theory. According to T. Matolcsi, P. Ván, and J. Verhás (2005), the components of a physical theory comprise relevant physical quantities, the differential equations that govern their processes in space-time, and variational and symmetry principles. Thus, theoretical physicists are able to perform their jobs effectively without a comprehensive understanding of the theories' composition, despite the fact that the latter are their primary products and essential intellectual tools.

It is also instructive to understand physical theory from the perspective of a professional experimental physicist who leans towards a philosophical interpretation of experimental physics (Parravicini, 2024: p. 177): "By 'physical theory' we mean a 'scientific theory' within physical science. Namely, it is a set of concepts and interpretations, based on a system of definitions, demonstrations, and methods: this builds an explanation of the phenomena investigated by physics, according to demonstrative procedures typical of the experimental method and of the mathematical language, which is specific to this discipline, in order to obtain universal and necessary explanations."

However, it is easy to see that this view is also incomplete, as it does not consider many components of the theory as a complex, polysystemic system.

In any case, this is a clear example of a general vision of theory with a rather limited resolution. The devil is in the details. Several such details were considered in (Burgin, Kuznetsov, 1994).

(*To be continued*)

Acknowledgments

This work was supported by the Institute of Physics of the National Academy of Sciences of Ukraine (Grant No. 1.4.B-219) and Skovoroda Institute of Philosophy of the National Academy of Sciences of Ukraine (the project 'Knowledge in action: logical, epistemological and institutional-normative dimension').

We are grateful to the Ukrainian Armed Forces and our Western allies, who made the preparation of this article possible.

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Received 16.06.2025
Accepted for publication after review 31.07.2025
Signed for printing 03.11.2025

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З ЯКИХ СКЛАДНИКІВ ПОБУДОВАНА
КОНКРЕТНА НАУКОВА ТЕОРІЯ? (ЧАСТИНА 1)

Під конкретними теоріями розуміють наукові теорії, за допомоги яких досліджують певні типи матеріальних реалій або явищ (елементарні частинки, плазма, надпровідні матеріали, квантове тунелювання, хімічні реакції, регуляція генів, рух тектонічних плит, Всесвіт). Після розгляду різних бачень поділу теорії на компоненти, запропонованих деякими видатними вченими (такими, як Ісаак Ньютон, Джеймс Клерк Максвел, Гайнрих Рудольф Герц, П'єр Морис Марі Дюгем, Макс Карл Ернст Людвіґ Планк, Альберт Айнштайн, Норман Роберт Кемпбел, Персі Вільямс Бриджмен та Герардус (Жерар) т'Гофт) та філософами науки (такими, як Карл Раймунд Попер, Томас Самуель Кун, Імре Лакатос, Пауль Карл Фоєрабенд, Маріо Ауґусто Бунґе, Рональд Нельсон Ґіре, Джозеф Дональд Снід, Вольфґанґ Бальцер та Карлос Уліс Мулен), можна зробити висновок, що ці бачення не враховують усіх суттєвих компонентів та проминають багато важливих деталей, навіть щодо обраних компонентів. Неповні та недиференційовані бачення складу теорій, з одного боку, не враховують багато критичних ознак конкретної теорії, включно з її розвитком та зв'язками з іншими теоріями. З іншого боку, вони часто породжують псевдопроблеми, прикладом яких є популярна теза про несумірність класичних та квантових теорій. Оскільки теорії лежать в основі сучасних наук, їхні редуковані бачення призводять до надмірно спрощеного та занадто загального розуміння науки та її прогресу. Стаття розкриває значення та корисність полісистемного аналізу конкретних теорій та їхнього розвитку для історії, філософії, соціології та педагогіки науки. У першій частині статті описано складники теорій та погляди на них фізиків. У другій частині буде розглянуто погляди філософів на теорії та викладено висновки. Ми наголошуємо, що в першій частині ми описали місток між нев'ядущим зразком наукової теорії Ньютона та найновішими тенденціями в інтерпретації сучасних фізичних теорій. Це яскравий приклад західної наукової традиції тяглості та заразом змін, завдяки чому кінцевий продукт виглядає інакше, але його структура залишається стабільною, знайомою та зручною для професіоналів. Ось чому сучасному вченому цілком можливо читати Ньютона та знаходити твердження, корисні для своєї практичної діяльності, а про конкретні перлини, створені генієм, годі й говорити.

Ключові слова: *конкретні теорії; складність; типи компонентів; полісистемний погляд; підсистеми.*