Complexity of Science versus Simplicity of Nature

Taha Sochi (Contact: t.sochi@ucl.ac.uk)
London, United Kingdom

Abstract: Modern science is the most complicated theoretical structure ever created by mankind (and possibly by any living species in our Universe). This is particularly true in modern physics which represents the most mature and elaborate branch of modern science. Nevertheless, modern science (and physics in particular) seems to make itself more complicated than necessary, and sometimes modern science seems to make itself complicated unnecessarily. This "simplistic" view to science may be supported by the fact that Nature (despite our acknowledgment of its complexity and sophistication at the level of fine details) seems to be governed by some rather simple rules and general laws which may be able (if comprehended and employed correctly) to make our science much simpler than what we actually have. In this article we try to highlight some issues about potential simplification of modern science (and physics in particular) which (i.e. simplification) could be one of the greatest goals and advancements (if achieved) of future science. In our view, the simplification of science is fundamentally related to the issue of unification of physics and the search for the so-called "theory of everything" (i.e. in a sense different to what is currently perceived and envisaged).

Keywords: Modern science, modern physics, theoretical physics, future of science, future of physics, simplification of science.

Contents

1 Introduction

Modern science (and physics in particular) is an immensely elaborate and complicated theoretical structure. Moreover, this elaboration and complication grows exponentially with time. For example, classical physics is a rather simple and easy-to-comprehend subject in comparison to modern physics (and theoretical physics in particular). This may seem a natural consequence of the qualitative and quantitative growth of science over time where new scientific theories and insights supposedly deal with (and are challenged by) more complicated questions and more general issues. This may also be seen as a natural process in the evolution and progress of our knowledge and understanding of the Universe where simplistic and raw views and theories are replaced by more sophisticated and mature views and theories.

However, a panoramic inspection of contemporary science should reveal that behind all the complications of contemporary science, there is a simpler and clearer picture. In other words, the Universe (or Nature) is governed by simpler and more general rules and laws than what is suggested by the complexity and mess of our science. For example, we frequently meet in our science (which generally represents and reflects Nature) simple patterns of symmetry and general rules of optimization. This should raise the question that at least some of the complications of contemporary science may not be a necessity for understanding the Universe and the progress of knowledge but it may be a product and consequence (in part) of the scientific process itself, and hence simplification of science can be achieved without losing understanding or compromising progress.

In this context, it is important to acknowledge that progress and advancement in science are not necessarily associated with complication. In fact, sometimes the opposite is true. For example, the recent advancements in contemporary science (and physics, astronomy and cosmology in particular) over the last few centuries started with a simplification process where the complicated Geocentric model of the solar system was replaced by the simpler Heliocentric model, and this contributed beneficially to the subsequent advancements in physical sciences by the emergence of classical mechanics which marks the birth of contemporary physics (and other physical sciences such as astronomy, astrophysics and cosmology).

Another important issue to acknowledge is that simplification is an advantage to science in general (as demonstrated by the aforementioned example of Geocentric and Heliocentric models) and hence it should be one of the goals and objectives of science. Science, as an attempt to understand the physical world and exploit its resources, should hugely benefit from simplification. Accordingly, complication of science (and human knowledge in general) should not be accepted unless it proves to be a necessity for the progress of science and knowledge.

Anyway, the commonly-held conviction that respected and reliable science must be complex and difficult to understand (which naturally and frequently leads to deliberate attempts to complicate science unnecessarily) must be corrected and replaced. In fact, respected and reliable science must be as simple as possible, and this (i.e. simplification of science) in our view is always possible.

The main objective of the present article (as hinted by its title) is to advocate the idea that Nature could be much simpler than our science and hence it can be understood and enjoyed (through legitimate exploitation of its resources) by a simpler science. In other words, contemporary science may be complicated unnecessarily and for causes and purposes foreign to science and its objectives and goals. Our main argument in support of this idea is the (widely recognized fact of) existence of some simple and general rules that govern Nature's behavior where the understanding and employment of these rules can be exploited beneficially for building a new science (or reinventing the current science) that aligns with the simplification objective. To substantiate this argument by a specific example we suggest (and briefly investigate) the principle of optimization as one of the most obvious candidates for the aforementioned simple and general rules.

The plan for this article is that (following this introduction) we present and discuss briefly the example of the principle of optimization which we indicated already (see § 2) where we also consider its subtle relationship to symmetries and conservation principles which also represent a simple and general rule (or rather characteristic feature) of the physical world. In § 3 we investigate the main factors that cause complication of theoretical structures (including science which is the subject of interest in this article). In § 4 we touch on the issue of "theory of everything" which (in our view) is intimately linked to the issue of simplification of science where we advocate our preferred approach of "top-down" (that is fundamentally based on the empirical methodology of science) for tackling the issue of "theory of everything" as opposite to the currently-adopted approach of "bottom-up" (or what we describe as a "stitching together" approach). We finally conclude this investigation with an outline of the main achievements and conclusions of the present paper (see § 5).

2 Optimization as a Fundamental Principle of Science

The principle of optimization should be seen as one of the best examples (as well as indicators for the existence) of simple and general rules that govern the behavior of Nature and characterize its features. It is widely recognized among physicists (and scientists in general) that optimization is one of the fundamental principles of physics (and possibly the most fundamental principle of physics and science). In this section we briefly discuss this issue by listing a number of examples that support this fact by showing the involvement of the principle of optimization[1] in many physical subjects, phenomena and situations. The following list represents a sample of such examples:

1. The Lagrangian and Hamiltonian mechanics are based on the principle of optimization [1]. This means that the entire classical mechanics and large parts of classical physics are based on optimization. In fact, we can find many more-specific instances and applications of the optimization principle (and related variational methods and techniques) in various branches of classical physics such as statistical mechanics, thermodynamics and fluid dynamics (as well as related branches of science such as physical chemistry). For example, the second law of thermodynamics suggests that physical systems naturally tend towards a state of maximum disorder (which is essentially an optimization tendency). Similarly, the flow of fluids in fluid dynamic systems is regulated by energy efficiency rules that reduce the amount of work done or energy spent in the transportation of fluids (which is an optimization trend; see for instance [2]).
2. Fermat's principle of least time (which is widely used in geometric optics) is an optimization principle. This may be exemplified and demonstrated by the well-known derivation of Snell's law (and actually the laws of reflection and refraction of light in general) by this principle.
3. There are many examples in physics and physical sciences for the tendency (or bias) of physical systems toward an optimal state of these systems such as being at the lowest available energy level for their existing configuration (for instance, excited atoms tend to decay to their lowest energy levels). In fact, the stability of physical systems (which usually represents an ultimate goal for these systems) is generally reached through assuming an optimal state (i.e. by minimizing or maximizing certain physical quantities or parameters).

[1] "The principle of optimization" should be understood as a generic term that can loosely include various extremization (i.e. minimization and maximization) and variation principles, rules, approaches, techniques (and so on).

4. Modern field theories heavily rely in many of their formulations and details on the optimization principle and variational methods (e.g. through the use of the principle of least action). For instance, quantum field theory uses optimization principles and variational methods to describe and formulate the interaction of fundamental fields.
5. There are many aspects in classical and modern electromagnetism that are based on (or related to) the optimization techniques and variational methods, and this includes Maxwell's equations (or at least some of them) which may be derived by these techniques and methods.
6. There are many aspects in quantum physics that are based on (or related to) the optimization techniques and variational methods. In fact, even the use of the Hamiltonian operator in quantum mechanics (at least in one of its main formulations) should indicate optimization (see the first point in this list).
7. General relativity can be regarded as an optimization theory through (for instance) the concept of geodesic [3]. Moreover, there are derivations of the field equation of general relativity by optimization arguments and variational methods.
8. Many engineering processes and techniques are inherently based on physical optimization. For example, physical annealing (which is investigated in materials science and used in metallurgy) is fundamentally based on the tendency of thermodynamic systems to reach their lowest energy configurations (when given sufficient time and opportunity to do so).
9. The theory of evolution is partly based on (or related to) the optimization principle, e.g. through the rules of natural selection which optimizes certain properties and features (for instance, Nature favors traits that enhance survival, fitness and reproduction success).
10. There are many examples of physiological and biological optimization in the physiological processes and biological activities of living organisms (i.e. beyond the optimization related to the evolution of species as demonstrated, for instance, by natural selection). In other words, optimization works at the level of living individuals as well as at the level of living species.
11. Many behavioral aspects of the living species are regulated and controlled by optimization rules and objectives. For instance, the Pavlovian conditioned response theory is based on an optimization philosophy (i.e. the satisfaction of animal, which affects its behavior and learning process, is optimized by making the animal get maximum reward by least action).
12. In fact, even the widespread use of the optimization methods and techniques in modern

computing (including some branches and applications of artificial intelligence)[2] is an indication of the wide extent and generality of optimization in Nature because many of these methods and techniques are actually based on (and even simulate) natural processes and phenomena in the physical world, and hence their widespread use should indicate and reflect the wide extent and generality of optimization in Nature.

More generally, we find extensive use of the optimization and variational methods in many disciplines (not only computing) related to modern science (thanks to the wide extent and generality of optimization in Nature and the strong influence of physics and physical ideas and methods in general). This should indicate and reflect the fundamental role and exceptional importance of optimization in Nature (which is reflected in science and knowledge in general) and its wide extent and generality.

2.1 Symmetries and Conservation Principles

Symmetries and conservation principles represent another simple and general feature (or rule) of the physical world (and hence of science). However, they are (unlike optimization) commonly linked to physics (or at least they are not as widely known and recognized in other branches of science as optimization). Moreover, conservation principles[3] (as supposedly represent demonstrations of certain symmetries in Nature) may be linked subtly to optimization and hence we do not need to complicate the situation by introducing another general principle (which is potentially different from optimization and hence it may compete with it). For instance:

1. Symmetries represent economy in the states and configurations of physical systems and hence they are subtly linked to optimization.
2. Conservation represents economy in action (related to creation and annihilation) and hence it is subtly linked to optimization (by reducing action).
3. Conservation usually represents constraints in the optimization processes and problems (and hence conservation and optimization usually work together and hand in hand to achieve certain objectives and reach specific targets).

In short, we can consider symmetries and conservation principles as a subtle demonstration

[2] Examples in this regard may include simulated annealing and genetic algorithms as well as many modern techniques in machine learning (and artificial intelligence in general).

[3] The well-known and widely-recognized conservation principles are the conservation of: mass-energy, momentum (linear and angular), and electric charge. Other less-known conservation principles (related to particle physics and rather limited in application) include conservation of: baryon number, lepton number and strangeness.

of optimization rather than being a totally different aspect or feature of the physical world. Nevertheless, symmetries and conservation principles deserve (and hence should be given) a special attention in the investigation of the simple and general features (or rules) that characterize the physical world and govern the behavior of Nature (especially within the subject of physics) with consideration of their subtle relationship to optimization.

3 Causes of Complexity

The complexity of theoretical structures in general and science in particular arises from a number of factors; the main ones in our view are conceptualization and specialization (which will be investigated in the following subsections). In fact, there are many factors and causes for the complexity of theoretical structures. However, most of these factors are specific to certain situations and instances and arise from particular reasons and causes and hence they cannot be regarded as general causes for complication. So, our intention in the present section is to investigate those factors which are general and have special importance for the objective of simplification of science (and hence they require exceptional attention and consideration in this investigation).

3.1 Conceptualization

Conceptualization is the first main cause of complication (as well as simplification) of any theoretical structure. In our view, theoretical structures are no more than elaborate high-level linguistic constructions whose purpose and objective is to reflect the reality of the outside world.[4] In other words (appropriate to our subject and context), science (as a theoretical structure) is no more than a high-level language for representing and depicting the reality of the physical world in its diverse aspects and perspectives.

It should be rather obvious that any linguistic process is actually a conceptualization process in the sense that we create certain concepts and models to represent the objects and phenomena of the given reality of the outside world. Accordingly, any theoretical structure (which supposedly reflects and represents a given reality of the outside world) is a mix of reflection/depiction of the given reality and invention/creation of our mind, where the reflection/depiction side represents the objective component of the theoretical structure while the invention/creation side represents its subjective component. In simpler words,

[4] We refer the reader in this regard to chapter two of our book [4].

any theoretical structure partly belongs to the reality of the outside world and partly belongs to the "reality" of our brain.

This means that the conceptualization of any given reality of the outside world is not unique, because even though the reality of the outside world is unique (or this is what we hypothesize and assume as part of our epistemological principles; see [5]), the "reality" of our brain is not unique since it is subject to our individual characteristics, capabilities, experiences, and so on. We may even claim that there are many (and possibly infinitely-many) ways for conceptualizing any (or almost any) reality of the outside world. In fact, this should partly explain and justify one of the main epistemological principles of science which we embrace and advocate, namely "the principle of non-uniqueness of science" (see [5]).

Now, since the conceptualization of any given reality of the outside world is not unique, then we should have (at least in principle and by potential) complicated versions of conceptualization of a given reality as well as simplified (or less complicated) versions of conceptualization of that reality. So, complication (as well as simplification) is (at least in part) a matter of deliberate choice and selection rather than a necessity or a fate and destiny. This means that to a certain extent we are free to choose between complicating our science and simplifying it.

However, to be able to make such choices we need to have two things:

1. A conviction of the "non-uniqueness of science" view (or principle) to justify our search for simpler alternatives (and potentially more complicated alternatives).
2. Serious attempts and efforts to make this view a reality by thinking about (and trying to create) new theories or/and simplifying the existing theories.

In short, simplification (as well as complication) of science is at our disposal when we decide and choose to do so.

3.2 Specialization

Specialization is the second main cause for complicating the theoretical structures. To be more clear, the theoretical structures at the level of overall and broad picture are generally simpler and easier to comprehend than they are at the level of fine details and specific features. This is because the panoramic view is inherently simpler than the detailed view since many of the complications of the details naturally dissolve and merge in the overall picture. In simpler words, specialization (in the sense of going through the fine details and specific issues) is a natural cause for complication, and this could be one of the meanings of the common idiom “the devil’s in the details”.

In this regard it is useful to note the following points:

1. The creation of theoretical structures may follow a “bottom-up approach” (where we start from the details to reach the overall and panoramic picture which represents the general view), and may follow a “top-down approach” (where we start from the overall picture to build and elaborate the fine details). Although these approaches represent opposite philosophies and methodologies for constructing and elaborating theoretical structures, they usually contribute positively (if employed correctly and appropriately) to building a healthy and realistic theoretical structure. In other words, both these approaches are legitimate and useful but each approach has a specific role and function in the construction process, and hence they ideally should be used together (by combining and merging them in the construction process) where each approach is assigned to its specific and appropriate role to achieve the ultimate goal of constructing a healthy and realistic theoretical structure (i.e. about the specific reality which the theoretical structure is supposed to represent and reflect).
2. With regard to the construction of theoretical structures in the field of physical sciences (which are inherently about Nature and hence they should largely follow an empirical methodology), we should ideally start from collecting some empirical details or data (based on experiment and observation) to build an *initial* overall picture, and this should represent the role and function of the “bottom-up approach” in the construction process. However, as indicated already this overall picture is initial (since it is usually contaminated with details which are irrelevant, and even inappropriate, to the construction of a realistic theoretical structure) and hence we need to improve or “polish” the initial overall picture through the use of the “top-down approach” to build a final (or possibly an improved) overall picture. So, the role of the empirically-based initial overall picture is to provide an initial understanding that represents the substance (or inspiration) for the application of the “top-down approach” for building the final (or improved) picture. We may also describe the initial overall picture as a precursor for the final (or improved) overall picture which we obtain through the application of the “top-down approach”. In fact, this process (i.e. of going through building an initial overall picture followed by constructing a final or improved overall picture) usually needs to be repeated where the repetition of this process follows the continuous advancement and progress of science empirically and theoretically. So, this cycle of “bottom-up” followed by “top-down” should continue as long as science is making progress and not in a standstill state or stagnation situation.

3. According to the previous point, the "top-down approach" is not inconsistent with the empirical methodology (which is the legitimate methodology in science) because the "top-down approach" should be based on the general understanding that is based on the empirical approach (through the use of the "bottom-up approach" for building the initial picture). Moreover, any result reached through the "top-down approach" should be tested against the available empirical data and partial theories and views which are obtained directly through experiment and observation (and generally during the "bottom-up approach" to get the initial overall picture). In short, the "top-down approach" is essentially empirical in nature due to its reliance on the initial picture and through its validation and tests against the empirical data and empirically-based partial theories which are obtained during the application of the "bottom-up approach" and the construction of the initial picture.
4. The issues that we investigated in the present subsection (namely specialization and the related issues of "bottom-up" and "top-down") are closely related to the issue of "theory of everything" which will be investigated next (see § 4). In fact, even the issue of conceptualization (which we investigated in § 3.1 mainly from the perspective of complication and simplification) is related to the issue of "theory of everything" because the "theory of everything" is essentially a simplification attempt (by dissolving the complexities of fine details into an overall simple picture) and hence our investigation about conceptualization demonstrated (in certain sense) the possibility of this kind of simplification (i.e. through the "theory of everything") and the possibility of doing this in a simple form. So, roughly speaking we can say: the investigation in § 3.1 was about the possibility of the "theory of everything" simplification and the possibility of having this kind of simplification in a certain simple form, while the investigation in § 3.2 (i.e. the present subsection) is about the optimal way to do this kind of simplification (where the meaning of this should be clarified further in § 4).

4 The Theory of Everything

The elusive "theory of everything" seems more elusive when we inspect the recent developments in modern physics and the additional complications introduced by the excessive theoretization and mathematical sophistication of theoretical physics which make finding such a theory more challenging (and potentially impossible). Moreover, the infestation of modern physics (and theoretical physics in particular) by illusions and hallucinations should cast a shadow on the validity and credibility of such "theory of everything" (if reached) from the perspective of being a genuinely scientific and purely physical theory since it can be a theory that includes in "everything" things which are not scientific or physical at all. For example, it is difficult to imagine a "theory of everything" that is based on the current modern physics which does not include things like dark matter, dark energy, creation, multiversism, and other similar elements (i.e. concepts, models, principles, etc.) whose physicality is questionable.

In fact, additional complications and difficulties are introduced to the current project of "theory of everything" through the adoption of the "stitching together" method (which is essentially a "bottom-up" approach) where the unification of physics into the "theory of everything" is sought through combining and merging a mosaic of inhomogeneous theoretical structures (i.e. the different branches and theories of physics such as electrodynamics and gravitation) that represent a collection of theories created and developed by different individuals and groups of scientists in different eras of history reflecting different levels of scientific, philosophical and epistemological development and dealing with largely separate physical phenomena.

Anyway, in our view the desperately-sought "theory of everything" could become more viable and reachable if it is approached from a different direction and by a different methodology where the search for this theory starts from some general and simple rules or principles (such as the optimization principle; see § 2) that reflect the behavior of the entire physical world (and hence unify the entire physical knowledge) by reflecting the main and most comprehensive characteristics of Nature. Such rules and principles should (by nature) be well tested (or at least has the ability to be well tested) and rather obvious and hence their generality (and consequently their unifying ability) and physicality should be well established. This means that we avoid the danger of being lost in the mess of specialization and excessive theoretization and mathematization (as well as the danger of being tricked by illusions and hallucinations that do not reflect genuine physical phenomena or belong to the reality of the physical world).

Accordingly, the currently-adopted "stitching together" method (which is essentially a "bottom-up" approach) in tackling this issue (where the search for the unifying theory of everything starts from specific theories and branches of physics such as electromagnetism, gravitation, quantum physics, and so on, to reach an ultimate unification theory of these theories and branches) should be replaced by the more appropriate "top-down approach" for tackling this issue (where the search for the unifying theory of everything starts from some proposals of unifying principle/s and rule/s that can be applied-to and tested-by the current physical knowledge as represented by the aforementioned theories and branches). As explained in § 3.2, this is entirely consistent with the empirical methodology (which is the legitimate methodology in science) where the fine details (represented by the empirically-collected data as well as the individual specific theories and branches of physics which are supposedly well tested) provide the substance, inspiration and test bed for the overall picture that is essentially obtained through the "top-down approach".

5 Conclusions

We outline in the following points the main achievements and conclusions of the present paper:

1. The main thesis of this article is that Nature (despite its complexity at the level of fine details) is rather simple because it is regulated and governed by simple and general rules and characterized by simple and general features. This should raise a question about the possibility that Nature could be simpler than our modern science and hence our science may be complicated unnecessarily.
2. Simplification, rather than complication, should be regarded as one of the main virtues and advantages of science and hence it should be a goal and objective for science (noting that current science largely follows an opposite philosophy by exalting and glorifying complication and perplexing of science through excessive theoretization and mathematization).
3. We investigated the principle of optimization as a well known example or instance of the aforementioned simple general rules that govern the behavior of Nature and characterize its features, and hence it could be a foundation (perhaps with other foundations) for physical sciences (and possibly an element in the unification of physics and the search for a "theory of everything").
4. We presented a number of examples and instances of the principle of optimization in various branches of science. We also discussed briefly the issue of symmetries and conservation laws (which also govern and characterize the behavior and features of Nature and propagate throughout physical sciences) as a potential application or variation of the principle of optimization (or at least a partner to the principle of optimization in building simpler science and unifying physical theories).
5. We identified two main causes for the complication of theoretical structures (including science), namely: conceptualization and specialization. With regard to conceptualiza-

tion, we advocated the idea that complication/simplification to a certain degree is a matter of choice rather than necessity. With regard to specialization, we identified the link between simplification and unification (which will be outlined next) and hence advocated the "top-down" approach for constructing realistic theoretical structures in their unified final form (or picture) where this process should benefit from (and go initially through) the "bottom-up" approach to get empirical legitimacy as well as an initial overall picture (representing a substance and inspiration for building the final overall picture).

6. Simplification and unification (of theoretical structures in general and science in particular) are intimately linked. This implies that simplification should help in unification, and unification could be achieved by simplification through the search for general and simple rules and features. Moreover, unification can be seen as an attempt and project for simplification. The intimate link between simplification and unification should directly impact the issue of "theory of everything" (as a unification project and hence it is a simplification process through searching for general and simple rules and features).
7. The "stitching together" method for building a "theory of everything" by contemporary physicists is essentially a "bottom-up approach" that is more appropriate for building an initial overall picture. Moreover, it is largely confined by the details of contemporary branches of physics which (on the one hand) restrict the development of a healthy and truly unifying theory and (on the other hand) intoxicate any such theory with the illusions and hallucinations that infest modern physics (especially the branches of theoretical physics). Our preferred method for building such a "theory of everything" is by adopting a "top-down approach" that benefits from the existing branches of physics (as well as the empirical data) as substance, inspiration and test bed for developing such a unifying "theory of everything" through the search for simple and general rules and features that govern and characterize the natural world.
8. We should finally note[5] that the empirical methodology (which should be in control of scientific development instead of the theoretical and speculative methodology which currently dominates this development in fundamental branches of science and physics) is essentially a simplification approach where actual facts (extracted empirically and processed and analyzed by simple general rules) dominate and govern the evolution of science.

[5] This note is actually about an issue related (rather indirectly) to our investigation in this paper. The main purpose of this note is to emphasize on our view (which we consistently advocate) about the priority and necessity of empiricism in physical sciences.

References

[1] T. Sochi. *Introduction to the Mathematics of Variation.* Amazon Kindle Direct Publishing, first edition, 2021.

[2] T. Sochi. Energy Minimization in Fluid Flow through Tubes and Networks of Various Geometries. *arXiv:2504.13546*, 2025.

[3] T. Sochi. *General Relativity Simplified & Assessed.* Amazon Kindle Direct Publishing, first edition, 2020.

[4] T. Sochi. *Critique of Logical Foundations of Induction and Epistemology*. First edition, 2023. DOI: https://doi.org/10.6084/m9.figshare.27002851.v1.

[5] T. Sochi. The Epistemology of Contemporary Physics: Introduction. *arXiv:2410.00040*, 2024.