The Epistemology of Contemporary Physics: Introduction

Taha Sochi (Contact: ResearchGate)
London, United Kingdom

Abstract: This is the first of a series of papers that we intend to publish about the epistemology of fundamental physics in its current state. One of the main objectives of these papers is to improve our understanding of fundamental physics (and modern physics in particular) from an epistemological and interpretative perspective (i.e. versus formal perspective). Another main objective is to investigate and assess the merit of searching for a unified physical theory (the so-called "theory of everything") considering the fact that contemporary physics is 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 and hence such unification may mean "stitching together" an inhomogeneous collection of theoretical structures which may be clumsy (if not impossible) at least from an epistemological viewpoint.

Keywords: Epistemology of science, interpretation of science, philosophy of science, contemporary physics, fundamental physics, unification of physics, theory of everything.

Contents

1 Introduction

Contemporary physics is a collection of theories created and developed by different individuals and groups of scholars in different eras of history reflecting different levels and stages of scientific, philosophical and epistemological development. These theories deal with the physical world as separate phenomena (such as electromagnetic phenomenon and quantum phenomenon) where each phenomenon has its own collection of laws, rules, principles, methodologies, concepts, terminologies, and so on. This simply means that contemporary physics is an inhomogeneous collection of theoretical structures that may not be compatible with each other from an epistemological viewpoint since they rest on different theoretical infrastructures.

Although contemporary physics works fine at the formal and practical level in most areas, it faces serious challenges at the epistemological and interpretative level as seen, for instance, in the failure so far of having a sensible and reliable interpretation for quantum mechanics which is engulfed by many perplexities and "paradoxes" despite its undeniable success at the formal and practical level (see for example [1, 4]). This dilemma (in our view) is not limited to quantum mechanics but it extends to other physical branches and disciplines that are largely seen as well-understood and -interpreted (e.g. the mechanics of Lorentz transformations which is commonly known as special relativity; see for example [2, 3, 6]). In fact, even the "humble" classical mechanics of the seventeenth century is not well-understood at the epistemological level from various aspects; the simple example is the interpretative meaning and significance of Newton's third law despite its obvious simplicity and "triviality" from a formal and practical perspective.

Apart from these interpretative and epistemological difficulties and the challenges they represent from this perspective, this inhomogeneity of contemporary physics and the epistemological challenges it faces (whether these epistemological challenges are the result of this inhomogeneity or not) should put a question mark (at least from an epistemological perspective) on the search for a unified physical theory (i.e. "theory of everything") which is the ultimate dream of contemporary physicists. In other words, is it possible or sensible or legitimate to have a consistent unified physical theory when this unified theory is no more than a "stitching together" of a collection of incompatible theories related to separate (and sometime unrelated) phenomena? Moreover, let's assume that we obtained such a theory by "stitching together" the branches of contemporary physics and hence we got a "theory of everything" from a formal perspective, is this theory a "theory of everything" from an epistemological perspective, i.e. can this formal "theory of everything" provide an "understanding of everything" by providing a sensible and reliable "interpretation of everything".

The physical world is single and homogeneous and hence any "theory of everything" that really reflects this single and homogeneous world should be (at least for the purpose of being epistemologically sensible and understandable) single and homogeneous not a "stitching together" mosaic of theoretical structures that belong to different historical eras where they depict and formalize separate physical phenomena and aspects of the natural world.

In the present series of papers we intend to address these issues by investigating and assessing the epistemology of contemporary physics where in each paper we investigate one aspect (or branch or discipline) of contemporary physics. To summarize, the main objectives of these papers are:

1. Trying to dive deep into the epistemological significance and the interpretative meaning of the main branches and aspects of contemporary physics to have a better understanding of the current state of physics from an epistemological and interpretative perspective. In other words, we want to bypass the usual (or conventional) treatment and employment of physics as a collection of formal recipes for "doing business" to reach their philosophical and epistemological significance and spirit in a human-understandable language away from their formal symbolic and perplexing forms.
2. Trying to investigate and assess the consistency of contemporary physics from an epistemological perspective and hence investigate and assess the merit of searching for a unified physical theory (i.e. "theory of everything") from an interpretative and epistemological perspective (if not from a formal and practical perspective).
3. Trying to suggest and propose alternatives to the current approaches for tackling the subject of unification of physical theories which have failed so far to produce a single unified physical theory (epistemologically as well as formally) despite the huge efforts and despite the many partial successes at formal level.

As indicated earlier, the current paper is the first of a series of papers that we intend to release about the epistemology of contemporary physics in its fundamental forms and formulations. In this introductory paper we intend to lay down the foundations that we need and will use in this investigation. In fact, the content of this paper is partly based on our previous investigations about these issues (see for instance [4, 5]) and hence the interested readers should refer to our previous books and papers for more detailed treatments of these issues.

2 The Objectives of Science

There are two main objectives for science in general:

• **Practical objective** which is conquering the world and benefiting from its resources (or making use of it).

• **Theoretical objective** which is understanding the world (or making sense of it).

It is worth noting the following points:

1. These are the *main* objectives for science *in general* as opposite to individual branches of science which have more specific and limited objectives (as well as these main and general objectives).
2. These two objectives are not limited to science but they generally belong to all types of rational knowledge (whether scientific in a technical sense or not).
3. These two objectives are not totally independent and hence better understanding usually leads to better conquest while better conquest generally leads to better understanding.
4. "Understanding" is an objective in itself (and hence it is as important as "conquest") because we are intellectual species and hence understanding is important to us like conquest although it may not be regarded to be as important as conquest since it does not seem to represent a direct biological need.

3 Formalism and Interpretation

Formalism and interpretation are the two main components of any scientific theory where the formalism largely reflects the practical aspect of the theory (such as its applicability and predictivity) while the interpretation reflects its human-understandable content and significance. This means that the formalism of scientific theory is largely about the practical objective of science while its interpretation is largely about the theoretical objective (see § 2). Hence, a scientific theory is not complete *in a strict sense* unless it is consisting of these two components (e.g. we believe that quantum mechanics is not a complete theory in a strict sense because its formalism has no sensible interpretation in our view).

Broadly speaking, the formalism of a scientific theory is the theory in its technical and rigorous scientific form (which is usually expressed by well-defined terminology and symbols and cast into strict qualitative or/and quantitative relationships which are usually in the form of mathematical formulae such as equations and inequalities), while the interpretation of a scientific theory is a rational explanation and justification to the formalism that can be envisaged as a model that we can understand and appreciate within our classic and macroscopic experiences and expressed in our ordinary language and concepts.

In fact, the interpretation of a scientific theory may be seen as the qualitative equivalent of the technical formalism of the theory (which is usually quantitative in form). However, in our view the interpretation is more than a qualitative reproduction of the technical formalism because the role of interpretation is not just to provide a more comprehensible and simple version of the theory (as represented primarily by the formalism) but it extends beyond this to areas and aspects like providing justifications, indicating causes and consequences, and correlating the formalism to observable physical entities and quantities.[1] Moreover, interpretation may not necessarily be a qualitative reproduction of the formalism, as seen for example in the *alleged* interpretations of quantum mechanics where the formalism is based on obscure paradigms like wavefunction which has no sensible qualitative equivalent (within our classic macroscopic experiences whether practical or conceptual) if we have to accept these as legitimate interpretations *in principle*.

Accordingly, the interpretation provides an added value to the original theory (as represented primarily by the formalism) by vitalizing and rationalizing it through describing and explaining its contents and aspects using familiar concepts and understandable language and terminology although this description and explanation may not necessarily be a qualitative equivalent of its formalism if we have to avoid excluding certain potential interpretations (although their eligibility may be questionable).

It is worth noting the following points about the formalism and interpretation of a scientific theory and the relationship between them:

1. The validity and invalidity of the formalism and interpretation are generally independent of each other. Hence, we may have correct/incorrect formalism with correct/incorrect interpretation. For example, we reject special relativity as an incorrect interpretation (due to its axiomatic and logical weaknesses) although the formalism of the theory (i.e. the mechanics of Lorentz transformations) is generally supported by strong experimental and observational evidence and hence it is correct (i.e. in a practical, and possibly limited, sense). This similarly applies to quantum mechanics in its experimentally-endorsed formalism considering its various proposed interpretations which suffer, with no exception, from major weaknesses and defects (as indicated earlier; see § 1).
2. We may have more than one acceptable or valid interpretation to a given theory (as well

[1] In fact, one of the main roles and objectives of any interpretation (according to the explicit meaning and suggestion of the word "interpretation") should be providing a convincing explanation and justification to the formalism.

as may have more than one theory or more than one formalism that correctly describe a given physical phenomenon (see for instance § 5.3 and § 7).

3. We may not have an interpretation (or may not have an acceptable or valid interpretation) of a particular scientific theory even though the theory (as represented primarily by its formalism) is well established. An obvious example of this case is quantum theory whose all existing interpretations are questionable (in our view). In fact, some scientific theories may not even be interpretable (such as quantum mechanics in our view; see § 8.6 of [4]).
4. Ideal scientific theory is a theory whose formalism embeds its own interpretation, i.e. the formalism intuitively suggests its interpretation and hence the theory can be interpreted naturally and with minimal effort.
5. In certain branches of physics, the difference between the formalism and interpretation of scientific theory is rather delicate and subtle (or blurred). This is especially true in those branches of modern physics in which observation and measurement take a central role in the theory itself (as it is the case with special relativity and quantum mechanics). Anyway, it is very important to make the distinction between formalism and interpretation clear and transparent to avoid traps and pitfalls. For example, the confusion between formalism and interpretation in Lorentz mechanics (where the interpretation of special relativity is identified or mixed with the formalism of Lorentz mechanics) led to many troubles such as giving the credit of the empirical success of Lorentz mechanics to special relativity while putting the blame for the epistemological failure of special relativity on Lorentz mechanics (and hence we see the majority of physicists accept special relativity, despite its epistemological inconsistencies, because of the empirical success of Lorentz mechanics, while we see some physicists reject Lorentz mechanics, despite its empirical success, because of the epistemological failure of special relativity). Another example is from the quantum theory where the status of the issue of measurement (and wavefunction collapse which is one of the most troubling and problematic issues in quantum mechanics) was confused, i.e. whether it belongs to the formalism (as suggested by its inclusion in the axiomatic framework of quantum mechanics according to its commonly-accepted version) or it belongs to the interpretation (as suggested by its epistemological nature and content).

4 Logic

In simple terms, logic is a collection of rules and principles that regulate our rational thinking to ensure consistency (or rather *self-consistency*) and rationality. This means that the rules of logic should be respected in any rational form of thinking and knowledge and this should obviously include science both in its formalism and in its epistemology and interpretation. So in brief, the compliance with logic in science is an absolute necessity and hence any scientific theory that violates logic (explicitly or implicitly, directly or indirectly, formally or epistemologically, etc.) should be rejected without further ado because this violation means that the theory is inconsistent and irrational and hence it cannot be accepted as a form of rational knowledge.

Here we should point out (in reference to *self-consistency*) that logic determines the rules of subjective consistency in the epistemic system, while observation (in its comprehensive meaning that includes experiment) determines the rules of objective consistency with the external reality, meaning that the data and information obtained by observation are consistent with (and within) the epistemic system. In other words, logic ensures the internal consistency of the epistemic system while observation ensures the external consistency of the epistemic system, and thus logic and observation participate in ensuring the validity and consistency of the epistemic system, both subjectively (or internally or logically) and objectively (or externally or observationally).

So in brief, the basic principle upon which logic as a whole is based is the principle of self-consistency which is no more than the principle of non-contradiction in its comprehensive sense that includes similar relationships (which may be called contrariety or likewise). Accordingly, self-consistency is the essence and spirit of logic, and hence all forms, patterns, rules, principles and so on in logic are no more than details, examples and instances of the principle of self-consistency and means for achieving it in specific forms, particular models and different contexts. For example, the essence of syllogism (in its various forms) is to ensure that this principle is observed in the forms of inference and deduction in order to achieve consistency of the result in itself, with its premises, and within the epistemic structure on which the content of the syllogism is based.

The fact that the principle of self-consistency is nothing but the principle of non-contradiction in its general sense and its most comprehensive meaning plus the fact that self-consistency is the essence and spirit of the entire logic are what give logic a special place and hence protect it from skepticism and questioning and keep it away from disputes, controversies and compromises that may extend to many other things in any epistemic system (as indicated earlier in the first paragraph of this section). For example, we may accept a weak form of realism or causality (see § 5.1 and § 5.2) but we do not accept a weak form of logic.

We should finally note that the principle of self-consistency (upon which logic in general is based and which is the basic building block for establishing any epistemic system) is an instinctive principle that is theoretically manifested among species which are high in the rank of cognitive development. This principle, in essence, is instinctively inherent in all living beings and manifests itself in different forms in their behavior, actions and activities. In fact, it is the guarantee of their existence and survival by meeting their needs, satisfying their desires and enabling them to adapt to their environment. Without this principle (i.e. in its instinctive form) the biological rules and mechanisms that guarantee the survival and safety of the living organisms will be violated and disrupted.[2] This means that the principle of self-consistency (which is the essence of logic) has biological instinctive roots and did not emerge from nothing or originate from abstract conventions. In fact, this should add more justification to our previous claims that the compliance with logic is an absolute necessity and logic cannot be compromised or have a weak form.

5 The Epistemological Principles of Science

In the following subsections we outline the principles that underlie the epistemology of science and hence they provide the required foundations for the development of scientific theories (and interpretations in particular). However, it should be noted that these principles represent our viewpoint; moreover we present only those principles that are of primary interest and use to us in this investigation. We should also note that these are epistemological principles for knowledge in general and not only for science, i.e. science is just an instance which we specify here because it is the subject of our investigation.

5.1 The Principles of Reality and Truth

The epistemological foundations with regard to reality and truth are summarized in the following three basic principles which are pivotal not only to science but to all types of rational knowledge:

[2] For example, without it, the prey may seek its predator, the danger is prevented by what is worse, the thirst is quenched by what causes thirst, the hunger is repulsed by abstaining from food or eating poison, and so on.

• The **existence of reality** which means the existence of a real world beyond and outside the observer where the reality of this world is independent of the observer.
• The **uniqueness of reality** which means that this reality (as identified in the previous point) is unique and hence we have only one reality.
• The **uniqueness of truth** which means that we have only one truth which represents the honest reflection of the (existing and unique) reality (as identified in the previous points).

In the following points we discuss briefly some important issues related to these principles:

1. Scientists should consider these principles from a purely epistemological perspective rather than from an ontological perspective. Hence, the existence of reality, for instance, should not mean the existence of this "alleged" reality ontologically and in itself as an outside entity but the existence of this alleged reality epistemologically and for ourselves as an entity that we need to assume for building and justifying our scientific knowledge. In fact, the ontological reality (i.e. the ontological existence of reality) is a purely philosophical issue and is irrelevant to science and out of its scope and domain.
2. The principles of reality and truth should be regarded as an epistemological necessity because no rational and consistent science (and knowledge in general) can be built without these principles (noting that they are an ontological choice, i.e. we are free to accept or reject them from an ontological perspective).
3. The principles of reality and truth do not mean that the world should look the same to every species and individual. In particular, the uniqueness of truth does not mean that the truth is absolutely definite and determined. So, we can say the truth in its exact details is not unique (although it is unique in its essence and within the given conditions and circumstances). We may also say: the truth in its exact details is unique only for a given individual considering the entire set of conditions and considerations that determine the truth such as time, location, measuring equipment and so on. Also see § 5.3 and § 7.

5.2 The Principle of Causality

The essence of the principle of causality is the claim of an *intrinsic* association between a given event (or events) called cause and another given event (or events) called effect (where we use "claim" to indicate that causality cannot in general be proved, i.e. it is essentially a postulate or a hypothesis which is ultimately based on intuition; see §

6). This association supposedly makes the occurrence of the effect inevitable when the cause occurs. In fact, there are many aspects in the principle of causality that deserve inspection and attention. However, due to the limited space and scope of this paper we briefly discuss in the following points only those aspects which are most relevant to our subsequent discussions and investigations:[3]

1. Similar to what we said in § 5.1 about the principles of reality and truth, scientists should consider the principle of causality from a purely epistemological perspective rather than from an ontological perspective.
2. In our view, the principle of causality is an epistemological necessity for any rational theory (whether scientific or not) because without this principle no rational and persistent relations and explanations can be established (noting that this principle is a choice rather than a necessity from an ontological perspective). So, the epistemological demand for this principle is based on the epistemological demand for rationality in science (and indeed in any type of rational knowledge) as well as persistency which is a requirement for predictability. Potential limitations (as well as other aspects within the limits of size and scope of our investigation) of this principle will be inspected and assessed in the following.
3. As suggested already, the justification for embracing the principle of causality is its ability to provide a basis for predictability, rationality, consistency, persistency and so on. These factors should explain the need for the principle of causality as an epistemological necessity regardless of accepting or rejecting the causality principle at the ontological or philosophical level and regardless of its potential limitations. So in brief, no science or rational knowledge can be established without this principle in some shape and form although the details of the extension and limitation of this principle and its exact nature may be subject to debates and disputes.
4. A weak form of causality may be accepted (if we are forced to adopt such a weak form) as long as rationality can be maintained.[4] In fact, this should also apply to realism as represented basically by the principles of reality and truth (see § 5.1), i.e. a weak or partial form of realism may be accepted as long as rationality can be maintained.[5]

[3] We note that further discussions and details about the principle of causality can be found in [4, 5]. Moreover, other aspects of the principle of causality (which are more specific to certain branches and aspects of physics) will be discussed in the upcoming papers of this series.

[4] We note that maintaining rationality with such a weak form may require some modifications and adaptations to our basic conceptual framework which basically rests on our classical intuition.

[5] It is important to remember (see § 4) that this does not apply to logic (i.e. there is no acceptable weak form of logic) because any violation of logic is a violation of consistency and rationality which destroys the entire science and rational knowledge.

5. One of the main aspects of the principle of causality is the chronology of events in the causal relationships, i.e. the aforementioned *intrinsic* association is hierarchical in nature where the cause is supposed to produce the effect in a certain chronological order between the two, i.e. the cause and effect occur simultaneously or the effect follows the cause in time. Accordingly, this hierarchy does not allow the occurrence of the effect before the occurrence of the cause, i.e. the effect cannot *temporally* precede its cause. However, we may find in modern physics (or rather in the literature of some theories of modern physics) the so-called "delayed cause" relationships where the effect supposedly precedes its cause (although the "delayed cause" may not be really a cause and the relations may not be really causal). Anyway, delayed cause should violate the causality principle (and hence it should be rejected) if we accept the necessity of the aforementioned chronological order in the causal relationships.
6. Any talk about causal relationships across different worlds (e.g. macroscopic and microscopic worlds) whether in interaction or observation[6] should address the following three issues (among other issues):
   - The existence or not of absolute global time.
   - The meaningfulness of a unified concept or definition of "time" across all worlds.
   - The unified reality of "time" across all worlds.

   These issues should be naturally manifested, for instance, when dealing with the alleged "delayed cause" where these causal relationships involve occurrence or/and observation across different worlds.
7. Regarding the justification of the aforementioned *intrinsic* nature of the causal association, the internal sense of "constructional" relationship between the cause and the effect is what justifies this intrinsic nature. In other words, the repetitive association in itself (even if it is perpetual) does not imply causality unless we have a "sense" or "feeling" or "intuition" of a constructional and inherent relationship between the cause and the effect (where this feeling normally originates from our intuition which is generally based on

[6] "Interaction or observation" refer to the cases where the cause and effect are interacting in the same world or interacting across different worlds (i.e. one of them is in a world and the other is in another world) while the observer is in a world different from the world of both or one of them. This applies to all our physical observations (as well as theories, knowledge and so on) regarding the quantum and astronomical and cosmological worlds since we are classical (or macroscopic) in scale and hence we (as observers) cannot be "quantum observers" or "astronomical observers" or "cosmological observers" (e.g. when we observe a quantum phenomenon we observe it from our classical macroscopic world since we cannot penetrate the quantum world by becoming quantum objects or quantum creatures). In fact, we should accept the fact that we are trapped in one world and separated by an impenetrable barrier that detaches us from all other worlds (so all our observations to phenomena belonging to other worlds are actually indirect in this sense). See also § 6 and § 7.2.

our past experiences). In fact, this is inline with what we indicated earlier that causality is essentially postulated rather than proved. Accordingly, association in itself (even when it is repetitive and perpetual) in not sufficient to establish causal relationship. On the other hand, we may be justified to conclude a causal relationship between two events from a single observation based on our sense or feeling (or rather intuition) of this inherent relationship. This should indicate that even if we believe that the origin of the principle of causality is induction (and empiricism in general which is based on direct observation), the specific causal relationships require more than induction (or observation) since they are based on our internal sense and rational thinking that is based on our overall past experiences and knowledge (i.e. these relations require deduction and intuition as much as they require induction and observation). So in brief, perpetual association may not imply causality while casual association (or even hypothesized association) may imply causality where the ultimate criterion and origin of this implication stem from our intuition (see § 6) which is largely based on our past experiences and the presumed epistemic system (which is generally and ultimately based on our past experiences as well as our cognitive capabilities as intellectual species).

8. As indicated earlier, the causality relationship at the empirical level is no more than an association (continuously-repeated in the past and supposedly continuously-repeated in the future) between two events (or sets of events). The distinction between the cause and the effect in this relationship is decided either by the chronology of the events (i.e. the first-occurring is the cause and the second-occurring is the effect) or by the dependency of the events (i.e. the independently-occurring is the cause and the dependently-occurring is the effect). However, we should note that chronology and dependency may not be available in some causal relationships (e.g. simultaneous events not under our control) and hence we should rely on other means (mainly intuition) to distinguish between cause and effect. This should endorse what was indicated earlier that empiricism alone is not sufficient to establish causality relationships in general.

9. Whether the principle of causality is restricted to the classical (or macroscopic) world or it is valid even in the non-classical worlds (like quantum and astronomical and cosmological worlds) seems to be a matter that can be debated and disputed. However, as a requirement of rationality and consistency the principle of causality should be general and hence it should apply to the non-classical worlds as to the classical world. Yes, the specific causal relationships may be less obvious with regard to the non-classical worlds since we have no familiar experience or direct observation or justifiable intuition about the non-classical worlds and their phenomena and their relationships. Nevertheless, we

should note that most or all of the specific causal relations of the non-classical worlds are observed and deduced indirectly through classical macroscopic phenomena (represented typically by the reactions of the measuring devices which are generally classical macroscopic let alone our senses and cognitive capabilities which are obviously classical macroscopic) and hence the classical macroscopic relationships should be rationally projected onto the non-classical relationships. Yes, an issue may be raised about the extent of the validity of the principle of causality and possible restrictions on it at the non-classical level (to justify for instance the seemingly non-causal features of quantum behavior or the non-causal nature of the origin of Universe whether we believe in a deity or not).

5.3 The Principle of Non-Uniqueness of Science

In our view, science is not unique and hence in principle any physical phenomenon can be described, quantified and predicted correctly (i.e. without violation to the rules of logic or the principles of reality and truth; see § 4 and § 5.1) by more than one scientific theory.[7] Hence, any scientific theory should be replaceable (at least in principle) by another scientific theory where both theories are empirically correct and practically equivalent although they may be epistemologically different (in addition to their difference in formalism as well as potential difference in merit and advantages/disadvantages).

This principle is very important to science since it allows and legitimizes this sort of diversity in science which is not obvious and seems to be unrecognized among scientists and scholars. In fact, we feel that there is a common undeclared belief or consensus that science is unique and hence new theories are legitimate to emerge only as corrections or improvements (e.g. by generalization) or as minor and superficial modifications of old theories (as long as old theories are working in general). In fact, there are many examples and instances in science (e.g. in classical and quantum mechanics) that justify and legitimize our adoption of the principle of non-uniqueness of science.

5.4 The Principle of Economy

The essence of this principle, which may also be labeled with other tags like "Occam's razor" or the "law of parsimony", is that the scientific theory should be as simple as

[7] In fact, this principle in its general form is a principle of non-uniqueness of knowledge (i.e. rational knowledge). So, science (which is the primary interest in this investigation) is just an instance of knowledge.

possible, and hence if we have a set of theories (or formulations or interpretations, ... etc.) that are equivalent in their predictions and outcomes then we should choose the simplest one.

It is worth noting the following points about this principle:

1. The principle of economy (in some of its instances and interpretations) should imply the validity of the principle of non-uniqueness of science (see § 5.3).
2. The principle of economy does not necessarily require selection between different theories but it can be used in the creation or emergence of a single theory where economy considerations (e.g. in assumptions and postulates) are taken into account in its creation and formulation.
3. This principle does not represent a necessity or obligation and hence it can be violated (although this should be for good reason).
4. This principle should not only be used for the selection or creation of theories but it should also be used for the application of theories. In fact, the latter use is a common practice (and hence it gives more legitimacy and extent to this principle).

5.5 The Principle of Intuitivity

The essence of this principle is that certain theories (or theses or opinions or ...) are intuitive because they comply with our internal sense which is largely based on our past experiences, while others are not, and hence we can accept and reject certain theories or make preferences among them according to this intuitivity criterion (i.e. intuitive or more intuitive theories are accepted or preferred and vice versa). In fact, terms like "intuitive" and "counter-intuitive" are common in the literature of science when it comes to assessing and accepting or rejecting certain theories and opinions. This means that the use of intuitivity criterion for assessing and selecting theories in science is legitimate as a basis for making scientific judgments and preferences and is generally acceptable among the scientific community.

It is worth noting the following points about the principle of intuitivity:

1. The justification of this principle is essentially based on the theoretical objective of science as an endeavor for understanding the world and making sense of it (see § 2) noting that intuition is one of the main sources and manifestations of understanding.
2. The principle of intuitivity is generally not compulsory and hence it is mostly used in making preferences and voluntary choices (and so it is like the principle of economy in this regard; see § 5.4).

3. The principle of intuitivity is mostly related to the interpretation of theories (due to the link of this principle to the "understanding objective" of science which is the essence of interpretation; see § 2) although it may also be used for other purposes and in other contexts.
4. We must distinguish between intuition as an active element in the cognitive processes (see § 6) and the principle of intuitivity as an epistemological principle (which is the subject of the current subsection). While the first is rooted in the cognitive processes and is indispensable to them, the second is generally optional and not obligatory, and thus it is often used to select preferences and choose favorable options (as discussed earlier).

Also see § 6.

6 Intuition

In § 5.5 we discussed the principle of intuitivity and distinguished between intuition (or rather intuitivity) as an epistemological principle and intuition as an active element in the cognitive processes. In fact, intuition as an active element is the essence of our topic in this section, in which we address the role of intuition in the cognitive processes in general and its crucial contribution to the creation, development and maintenance of epistemic systems and structures.

In summary, intuition provides a mechanism for creating and synthesizing novel concepts (ideas, relationships, etc.) based on previous experiences and adapting available stereotypical concepts that are flexible and capable of modification as well as using and applying previously obtained concepts, in the face of subjective epistemic experiences and objective observations with the aim of integrating them consistently and rationally into the existing epistemic system or employing them beneficially within it.

By doing so, intuition actually ensures not only the enrichment of the existing epistemic system (by addition, generalization, extension, and so on), but also solving theoretical and practical problems for the system which cannot be solved without the intuition. In fact, intuition in the intelligent species plays a distinct and special role in achieving optimal adaptation and best satisfaction through enriching the epistemic system as well as resolving its complications and dilemmas and correcting its defects and faults. In brief, intuition plays a prominent role in building the epistemic system, rationalizing it, justifying it, complementing it, correcting its defects and shortcomings, filling its gaps, and so on.[8]

We should finally note that our intuition is created and formed by our classical macroscopic experiences and hence we do not have reliable intuition (since we have no direct experiences and direct observations) with regard to other worlds (e.g. quantum and cosmological worlds). Accordingly, we cannot make reliable judgments based on our intuition about other worlds since our intuition is "classical macroscopic" while the other worlds are not (see § 7.2).

7 The Nature of Human Knowledge

We discuss in the following subsections a number of general aspects about the nature of human knowledge (represented mainly by science inline with our scope and perspective) which are important to be aware of.

7.1 Humanism

Science is a product of mankind and hence it is characterized by the features of our cognitive system and how we think and interact with our environment (i.e. Nature). In fact, "humanism" does not only represent the "species" factor that enters in the determination and identification of the scientific process and knowledge, but it also includes many other factors such as cultural, social and personal factors. This, for instance, could partly explain the fact that we can have more than one correct scientific theory for describing and formulating a single physical phenomenon. As we saw earlier (refer for instance to § 5.3), any physical phenomenon can be correctly described and formulated by more than one scientific theory without violating the rules of logic or the principles of reality and truth (see § 4 and § 5.1). This is because any type of human knowledge is not really an ideal image-reflection (or image extraction) of reality but it is rather an interaction between the thinker and his environment (i.e. Nature) and hence this process (as well as its outcome which is the "extracted image") is affected by many humanist factors. In other words, the acquired knowledge (or the "extracted image") is actually an artistic impression of the thinker by Nature, i.e. it is more like an artistic impressionist painting than a

[8] Intuition is actually the essence of intelligence. In fact, the essence of artificial intelligence in our view is the formation of an "introspective intuition" for the intelligent computer by teaching it to benefit from past experiences through training and learning to extract models and patterns that are suitable for use in similar circumstances and situations by benefiting from collecting, classifying and analyzing the available information and data.

high-definition photograph or mirror-reflection.

So in brief, correct science does not represent a pure image or mirror-reflection of reality but it is a mix of reflection (or discovery) and invention (or creation) where this process and its outcome are affected and determined by many humanist factors (in the broadest sense of "humanist" as indicated above).

7.2 Scale of Observer

This factor may be seen as originating from the previous factor (see § 7.1) although we consider it separately due to its specificity and particular importance to science. The essence of this factor is that because we are a species of a given size (or rather scale), our sensory and conceptual experiences are acquired from the natural world (as perceived by us) on the scale that is comparable to our size (and in fact it is processed by our "humanist" nature which is the product of an evolutionary process on this scale and size). This means that the validity of the patterns (models, concepts, paradigms, etc.) that we acquire from our past physical experiences and we use as elements and prototypes in our scientific theories is generally restricted to certain scale and size and hence these patterns and models are not necessarily valid as physical models to the world on other scales and sizes.

This is based on the fact that the patterns and models (that are acquired and developed as abstractions from the physical world) are generally scale-dependent and hence some patterns and models may be compatible with certain scales but not with other scales. In other words, not all patterns and models are valid for any scale and size (or not all patterns and models are valid for describing the physical world at any scale and size). For example, the physical pattern or model of "wave" is acquired from our physical experiences at classical (or macroscopic) scale and hence the "wave" model may not be sensible to describe physical objects and phenomena at pico or femto scales because these scales were beyond our reach during the acquisition and development of the "wave" model and hence this model may not reflect the nature of the world at these scales. This similarly applies to many other concepts, models and patterns like "color" or "brittleness".[9]

In the following points we provide more clarifications about the "scale of observer" as an important factor that determines the nature of human knowledge (and hence as a

[9] In fact, if the invalidity of "wave" at pico or femto scales is suspicious the invalidity of "color" or "brittleness" (and their alike) should be obvious because they are fundamentally macroscopic. For instance, having red and green electrons or brittle and ductile atoms is obviously nonsensical.

factor that should be considered in the assessment and validation of scientific models and theories):

1. "Scale" is more general than "size" and hence it includes for instance speed (i.e. how fast or slow) and intensity (i.e. how strong or weak a certain physical property like electric charge or gravitational field). So in brief, "scale" is about the magnitude of a physical attribute (whether size or something else).
2. "Scale" is what determines the nature and essence of our intuition (see § 6) . Hence, considering "scale" factor our intuition is classical macroscopic because we are classical macroscopic creatures and hence our scale as observers which determines the nature and essence of our intuition is also classical macroscopic. This means that we can legitimately use our intuition only with regard to the classical macroscopic world not other worlds (i.e. quantum or astronomical or cosmological worlds).
3. The "scale" factor is actually about the *relative* magnitude as determined by the scale of the observer in comparison to the scale of the observed phenomenon. This is because the scale of the observer should primarily determine the scale of the observed phenomenon to which the patterns and models of the observer (as well as his intuition) are appropriate or not.
4. The "scale" factor is what makes quantum physics and Lorentz mechanics special among scientific branches and theories. This is because the extreme smallness of quantum objects and the extreme fastness of Lorentzian objects make them unusual and hence our physical models and patterns as well as our intuition (which were developed and acquired during our long evolutionary history dealing with macroscopic and slow objects) are not suitable to describe and quantify quantum and Lorentzian phenomena in a sensible and interpretable way (or at least this requires exceptional effort and attention and hence ignoring this fact leads to the complications and contradictions which are associated with quantum physics and Lorentz mechanics). In fact, we believe that this should similarly apply to other scientific theories and branches such as astronomy, astrophysics and cosmology where the scale in space and time (as well as other properties and attributes such as intensity of electromagnetic or gravitational fields) is unusual and hence it should not be considered or treated as classical or macroscopic. Accordingly, we may need to revise our principles, laws, assumptions, concepts, models, etc. that we are currently using in the investigation of subjects like astronomy and cosmology because these classical macroscopic principles (... etc.) may not be appropriate to use due to the scale factor. In fact, the failures in these fields (even by some supposedly "non-classical" theories like general relativity) could be a sign for the failure of our classical macroscopic

principles (... etc.) in these fields because of the scale factor.[10] These issues will be pursued in the forthcoming papers of this series.

5. The scale factor could have an effect even on some of our most fundamental and seemingly-intuitive concepts like space and time or our philosophical and epistemological patterns and paradigms such as our concept about physical reality and its nature. For example, the paradigms of "space" and "time" may not be applicable or appropriate (at least in their exact sense) at very large or very small scales (such as the scales of Universe and nucleon). Similarly, "macroscopic realism" may not be exactly applicable to "microscopic realism" (because "macroscopic reality" may not be identical to "microscopic reality"). In fact, even the epistemology can be scale dependent (especially in its detailed interpretative aspects).
6. Can the scale factor affect logic (and hence we may have modified or different versions of logic for worlds and realities of different scales such as quantum logic for the quantum world and cosmological logic for the cosmological world)? In fact, the invention (or discovery) of a new type of logic (which supposedly departs from the ordinary logic) that is valid to worlds at scales different to the "classical macroscopic scale of the ordinary logic" may be seen to be as legitimate as the invention of the non-Euclidean geometries (which depart from the Euclidean geometry). However, the "conceptual legitimacy" of any type of non-Euclidean geometry is based on its self-consistency (which is the essence of the ordinary logic as indicated earlier; see § 4) while its "practical legitimacy" is based on its agreement with physical observations (as well as its usefulness in this regard), i.e. external consistency (see § 4). Similarly, the "conceptual legitimacy" of any type of novel logic (such as quantum logic) should be based on its self-consistency (which originates from the ordinary logic) while its "practical legitimacy" is based on its agreement with "observations" (and its usefulness in this regard). This means that the legitimacy of any novel logic should be (at least partly) acquired from the ordinary logic (and hence to a certain extent it should be consistent with the ordinary logic). After all, we are classical macroscopic creatures (rather than quantum or cosmological creatures for instance) and hence even "quantum or cosmological logic" (i.e. the logic that belongs to the quantum world or cosmological world assuming the existence of such logic) should be subject to the rules of our "classical logic" (i.e. ordinary logic) to be "sensible" and "logical" to us. So in brief, at this stage we assume there is no scale-dependent logic (e.g. "quantum

[10] These failures are demonstrated, for instance, by the need for dark energy or dark matter or creation or nonsensical consequences like travel in time ... etc. which modern physics (in these subjects in particular) is full of.

logic" or "cosmological logic") as an alternative and substitute to the ordinary logic. Yes, there may exist some logical rules that are tailored specifically to worlds other than our classical macroscopic world (e.g. quantum and cosmological worlds) and they are consistent with the rules of ordinary logic. In this case, they are just instances of the rules of ordinary logic and hence they should be acceptable (although they are not expected to be of general validity like the rules of ordinary logic). So in brief, logic by nature is "classical" but scale-independent because we are classical creatures and logic is about our own consistency (or "self-consistency") and hence it cannot be changed in a fundamental way because we cannot be other than ourselves.

7. The aforementioned fact that our patterns and models, as well as our intuition, are scale-dependent should lead to an obvious intrinsic limitation in our ability to describe and interpret (in a realistic way) physical phenomena incommensurate to our scale. In fact, there are many examples in physics about this limitation and how we use (justifiably or unjustifiably) scale-limited patterns and models approximately or inappropriately to describe and interpret phenomena that are beyond our scale because we have no other (more realistic) choice. In fact, this highlights an essential limitation of science in general. After all, we are *humans* (see § 7.1) and of certain physical *scale* and hence we have no direct access to entities that are beyond our familiar experiences which are acquired and shaped according to our type and scale (and which generally form and shape our intuition; see § 6). Therefore, we may be content to use these scale-limited models and patterns (but cautiously) as approximate prototypes to investigate these entities. The danger, however, emerges when these models and patterns are treated (recklessly) as realistic and exact prototypes (and this sort of recklessness seems to be common in science as in all other aspects of human life).

7.3 The Evolution of Human Knowledge

We present in the following points a number of general notes about the evolution of human knowledge (represented mainly by science inline with our scope and perspective) which are important to be aware of:

1. The evolution of knowledge is probabilistic in nature (i.e. it is not deterministic). This means that the development or evolution of knowledge has an infinite number of probabilistic paths and ways, and in taking this or that path, it passes through crossroads whose choices and outcomes are determined by probabilistic and non-deterministic factors such as the historical and geographical conditions and circumstances, the prevailing

cultures, the neighboring and intersecting epistemic trends and currents, the personal characteristics and individual traits of the elite thinkers and influencers (such as scientists, philosophers, and even political leaders) as well as countless other factors. So, knowledge can probabilistically follow one path or another where different paths vary in their integrity, virtues, vices, inputs, and outputs. For example, a theory or an idea or a political event or a distinguished individual (with his personal characteristics) can contribute to the path of knowledge and its development positively or negatively (or positively in some aspects and negatively in other aspects, which is often the case) and may take it along one route or another. In brief, knowledge is a historical process and a probabilistic event that is not predetermined by necessities other than the necessities of the status quo, which is subject to countless overlapping and intertwined probabilistic factors. In fact, the process of knowledge creation and knowledge evolution is subject to the same rules that govern the emergence and evolution of living species, and hence these rules should explain the creation and evolution of different knowledge and epistemic systems just as they explain the emergence and evolution of different living species. It is important to note that this is one (and perhaps the most important) of the origins, causes, reasons and justifications for the principle of non-uniqueness of knowledge (and science in particular; see § 5.3).

2. Although the general trend in the evolution of knowledge is progress and advance, it may fluctuate and even go backwards from time to time. So, it is not necessarily that the present knowledge is better than the past knowledge or the future knowledge is better than the present knowledge. In brief, knowledge is integrative and progressive in the long term, taking into account short-term fluctuations, and hence although the general trend in the evolution of knowledge is to progress and move forward, it may stagnate, fluctuate, and even go backwards from time to time.
3. A theory or an idea or a development in the history of science may contribute positively in some aspects and negatively in other aspects. For example, modern physics (despite its undeniable empirical successes and achievements) is not necessarily a progress and success in its entirety (e.g. it can be a setback from certain epistemological perspectives).

References

[1] F. Laloe. Do we really understand quantum mechanics? *arXiv:quant-ph/0209123*, 2002.

[2] T. Sochi. Special Relativity: Scientific or Philosophical Theory? *arXiv:1610.05640*, 2016.

[3] T. Sochi. *The Mechanics of Lorentz Transformations*. CreateSpace, first edition, 2018.

[4] T. Sochi. *The Epistemology of Quantum Physics*. Amazon Kindle Direct Publishing, first edition, 2022.

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

[6] T. Sochi. Herbert Dingle and "Science at the Crossroads". *arXiv:2407.13697*, 2024.