Research paper

The possible source of the causal time arrow in geo-historical explanations

Gadi Kravitz

Department of Philosophy, The University of Haifa, Israel

ABSTRACT

My argument in this article, will be that nature, in general, and human nature in particular, suggests that, in principle, it is possible to derive the causal time arrow from several physical time arrows existing in nature and appearing to be unidirectional and irreversible phenomena. A more concrete argument will be that the assumption of a causal time arrow to which geologists resort in all geo-historical explanations, apparently originates in geo-historical time arrows concealed in unidirectional and irreversible physical-geological processes. I will illustrate this claim with a few examples of geo-historical explanations in the theory of plate tectonics, most of which are based on irreversible geo-physical processes. My final argument is a broader, of an epistemological nature, according to which the causal time arrow assumption used in logical-causative explanations in everyday life and in science, apparently “derives” in a way from the geo-historical time arrow, I will base this argument on the causal relationship and mutual influence that occurs in nature between geo-historical and evolutionary processes in animals, including developmental processes of the human brain and mind. From this reductionist argument, nicely integrated in the framework of evolutionary epistemology (EEM), it is possible to derive a wider naturalistic argument according to which, on principle, the laws of geo-historical physics can be reduced to the laws of logic and causality.

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1. Introduction

The question of “what is time?” has preoccupied and troubled many philosophers from time immemorial. Even today, many are concerned with this question, and, in fact, the puzzle of time remains unresolved. Therefore, instead of dealing with the question of whether time really exists or is just a figment of our thoughts, I will deal mainly with its basic and common-sense property, that differentiates between past and future - the asymmetric property, or in the metaphorical description, the time arrow - the unidirectional and irreversible geo-historical time arrow, based mainly on the laws of physics and geology. To achieve this goal, I will focus on the actualist logic, at the basis of geo-historical thinking that enables geologists to reconstruct the geological past of the Earth. First, I will argue that this logic, among other things, is based on the fundamental metaphysical principle according to which the cause always precedes the effect in time. Furthermore, this claim can be based on the geo-historical time arrow that empirically reflects geo-physical processes temporally irreversible. I can support this argument by several examples. Finally, I will argue a causal relation in a biological-physical sense between the geo-historical time arrow and the biological time arrow. In the last part of the article I will attempt to present an argument based on the Darwinian view of nature, that supports the central argument of this paper, concerning the possibility of reducing the geo-historical time arrow which is physical in essence, to the causal time arrow, that constitutes the solid base for any scientific and nonscientific explanation. From this reductionist argument, which is well integrated into the framework of evolutionary epistemology (EEM), we can derive a wider naturalistic argument claiming that, on principle, it is possible to reduce the geo-historical laws of physics to the laws of logic and causality.

2. The logical-causal argument structure in geo-historical explanations

One of the major challenges of modern science that is based on an empirical approach, is to explain the significance of allegations
related to the past. The verification process based on traces of the past is no more than our interpretation. The actualist approach in modern geology1 supposedly solves the problem by claiming that geological past events on Earth have current and future effects, and those can be verified directly by the geologist. The current actualist method assumes that on the basis of observations of geological phenomena that occur in the present, we can reconstruct and explain the geological past of the Earth in an analogical way (or with the help of analogies). In this sense, the geo-historian thinks back (towards the past) and thus, supposedly, artificially inverts the time direction of the geo-historical processes that occur in nature. What could justify the use of analogical explanations to reconstruct the geological past of the Earth from observations of geological events taking place in the present and from traces left by the geological past?

The analogical inferences are not applicable to conclusions that arise from assumptions on the basis of logical necessity, but are regarded as the most probable or the least probable. In geo-historical explanations, high probability is achieved thanks to the uniformity principle2 assumed by geologists, which conceals the fundamental generalization about causality that claims that the causal relationship between geological causes and outcomes does not change significantly over time, and therefore, we may assume that the same causes lead to the same outcomes. Specifically, in order to produce an analogy between two entities is to start by pointing out one or more attributes and revealing the similarity between them. An analogical inference is based on similarity of two or more things, and projecting this similarity on some other aspect of these things. In other words, an analogy is produced through the observance of common features between certain things and the conclusion that another similar feature can also be found in them. Such simple inductive inferences accompany our daily thinking regularly and without them we could not survive.

In a rather simple way, the pattern of arguments (inferences) by analogy can be described as follows:3

**Premise A** – thing A contains features 1, 2, 3, …

**Premise B** – thing B contains features 1, 2, 3, …

**Premise C** – it is found that thing A also contains feature 7.

**Conclusion** – therefore thing B also contains feature 7.

Since in geology we deal, among other things, with processes and geological phenomena that occurred a long time ago, the analogical inferences play a large role in our profession, and their level of complexity exceeds even that of most natural sciences4 that are not concerned with “deep time”5. In geo-historical explanations, in addition to the similarity between the features of geological phenomena and events, geologists are also looking for similarities between causal laws that generally comprise an explanation of the mechanism operating in the geological process. In this sense, they assume that the causal mechanism that produces the geological phenomena, does not change significantly (the uniformity principle) and, therefore, the relationship between cause and outcome in two similar geological phenomena does not change over time.6 Such a causal law permits the actualist to argue legitimately that, on the basis of observations of outcomes and process in the present, the geologist is able to reconstruct the past. Thus, actualism assumes that outcomes can explain or prove the causes just as causes can explain and prove the outcomes. How can we justify this claim? Or how can we justify that the causes originated from the outcomes? Like in the “chicken and egg” paradox, there's a certain kind of circularity – causes explain the outcome and outcomes explain the causes. However, we must keep in mind that contrary to the causes to which geologists mostly have no direct access, outcomes possess certainty and this accounts for their importance in geo-historical explanations. Typically, geologists are able to identify outcomes in the present quite clearly, but they do not have direct access to the past so the causes remain speculative. Geologists try to derive the causes from the outcomes, because empirically the outcomes are accessible and in this sense they are the most certain thing they have. This is similar to the scientific method presented by Decartes in his famous book “A Discourse on the Method” (Kenaz, 2010, p. 40–50, 90–107), since in the science of geology, causes cannot prove outcomes, but only explain and clarify them. The role of the causes is to explain or clarify the outcomes and the role of the outcomes is to test, validate, support and confirm the causes. Therefore, in order to explain causes, geologists assume them by a process of selecting the best hypothesis, which is sometimes called IBE – inference to the best explanation.

In this sense, an unproven, logically invalid “jump” of hypotheses (causes) emanating from facts (outcomes). In fact a recognized problem or question arises here: how can we prove the hypothesis which explains observations solely on the basis of outcome which are singular observation? In practice, in order to circumvent the difficulty and enable practical geological work to proceed, the actualists construct the past by building a theoretical conceptual system (uniformity principle) connecting the facts to the causes. With the

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1 For a more in-depth discussion regarding the historical development of this approach, see Romano (2015).
2 For a more in-depth discussion regarding the historical development of this principle, see Romano (2015).
3 It is crucial to note here that the uniformity principle is applied in order to provide logical necessity for inferences to the past. However, this need to have logical necessity in explanation is an issue for the rational reconstructions made by philosophers. In practice working geologists are far more interested in the fruitfulness of their proposed explanations (hypotheses) than in their logical necessity.
4 It should be noted that is not exactly how geologists use analogy in practice. In practice the use of analogy combines the inductive premises illustrated with an abductive inference that forms a causal hypothesis. For more details about this inference, see Kravitz (2013).
5 Concerning the methodological and epistemic differences between historical science and experimental science, see Cleland (2002).
6 About the role of analogical reasoning in geology, see Baker (2014).

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7 For a more in-depth discussion about the methodologies of geo-historical inferences and planetary sciences inferences, see: Peirce (1867, 1883), Chamberlin (1893, 1897), Gilbert (1896), Engelhardt and Zimmermann (1988) and Baker (2014). However, it must be remembered that analogical inferences are nothing more than inductive inferences, and in this sense they are not logically valid in a deductive sense.
8 The circularity of causality was already known to skeptical philosophers in ancient Greek. About this circularity see for example: Barnes (1990, p. 58–89).
9 About this process, see e.g., Peirce (1867, 1883), Chamberlin (1890, 1904, 1897), Gilbert (1896), Kitts (1977), Baker (2014), Kravitz (2012, 2013) and Cleland (2013). It should be emphasized that what I say here in not unique to just geology. In all scientific observations we can observe the outcome, but the cause is always a best hypothesis which we can test. The big difference is that in geology it is difficult to replicate the conditions needed to test that causal hypothesis and moreover geologists tend to eliminate multiple hypotheses when working in the field, at least according to the classic works on the philosophy of geology.
10 Here I am referring to the famous problem of induction raised by David Hume. Also, for this issue, see: Bonjour (2005, p. 47–69), Feldman (2003, p. 130–141).
11 Using the uniformity principle geologists, in fact, are trying to turn the conditional sentences “if C occurred, then E occurred” to an essential conditional sentence that event C is an essential condition for event E. In other words, they try to make the pattern of the sentence to patterns of the form “Event E occurred only if event C occurred” or “if event C and only event C occurred then event E occurred.” In these sentences if event C occurred then necessarily event E occurred but the converse case does not necessarily exist (in normal conditional sentences the first section is a sufficient condition for the final section and the final section is a necessary condition for the first section). For further details, see: Kravitz (2013, p. 29–32). I will hereby clarify some of the concepts, such as “sufficient condition” and “obligatory condition.” Sufficient Condition — Event H is a sufficient condition for the occurrence of event I only, and only if when event H occurs, event I too occurs, i.e., it is enough that H occurs for I to occur. Obligatory Condition — Event H is an obligatory condition for the occurrence of event I, only, and only if without the occurrence of event H, event I cannot occur, i.e., if H does not occur, I too cannot occur.
help of this conceptual system and relevant analogy to the case, geologists search for a feature or circumstance that is relevant to another because it has a causal effect on it. In that sense they actually construct the geological past instead of finding it, as the naive activist approach believes12. However, it should be noted that in order to evaluate analogical arguments, specific knowledge of causal relationships is needed and these can be revealed only by empirical tools — observation and experiment. This knowledge is perceived by geologists as a solid scientific base on which, in fact, all causal explanations of geo-history are based. Explanations based on causal relations alone are scientifically inadequate for geologists to explain the factors (causes) of the occurrence of geological phenomena observed empirically in the present (effects). Nevertheless, in spite of the difference between logical and causal implications13, geologists tend to use combined logical-causal arguments14. That means that logical arguments are used, but actually these explanations are causal explanations, based on factual arguments on the state of affairs regarding the geological state of the Earth in the past and in the present, that require testing of things in the world15. In other words, geologists believe there is an injective correspondence between logical reasons and implications expressed through linguistic epistemological creations (phrases and claims), and physical causes that actually occur in nature (ontological entities), alleged to be among them, dominate the nature of causal implications. In a sense, there is an unproven transition (“jump”) even here, and therefore the transition from the epistemological level to the ontological level of the world remains in doubt. The relevant questions in this connection are: is it possible to justify such a transition and if so, in what way? Can geologists practically avoid such a transition, and if so, how? Before attempting to answer these questions, I will briefly discuss a few philosophical issues, emerging from a look at the logical forms of arguments and geo-historical explanations, assuming that their use is justified, at least in practical sense. Actually, by using these arguments (explanations) geologists are attempting to fulfill the requirement of empiricism in modern science — that of testability.

Geologists have four possible structures (patterns) of logical-causal arguments at their disposal in order to provide a reasonable geo-historical explanation, in which C indicates cause and E indicates effect16. In all these arguments, sentences (1) and (2) are introductions (or premises) and sentence (3) represents the conclusion of the argument. The arguments are as follows:

1. If C occurred then E occurred
2. C occurred
3. Therefore, E occurred

II. If C occurred then E occurred
2. C has not occurred
3. Therefore, E did not occur

III. If C occurred then E occurred
2. E occurred
3. Therefore, C occurred

IV. If C occurred then E occurred
2. E has not occurred
3. Therefore, C has not occurred

A fundamental difficulty is associated with the first premise in these arguments, which I regard as the main theme in the current article. As you can see, in all inferences mentioned above, the first premise is identical and constitutes a causal conditional sentence, the first section of which refers to the cause, and the final section — to the outcome. From a formal logical point of view, this sentence claims that if the first section is real then the final section is real as well, and describes a relation between the first and final section without going into the reason (content) and meaning of the relationship between the two parts of the sentence. However, although this is a conditional sentence (material implication) integral to the entire logical argument, and to the content and meaning of the concepts it contains, it is also concerned with causal relations between the cause and the outcome, so that the final section of it isn’t necessarily implicated logically, or by definition, from its first section, but is due rather to the causal relation between them (any causal law). This premise, in fact, allows a causal argument to be presented as a logical argument. Presenting a logical argument does not involve any intention to determine something about the state of the world. The only intention is to indicate a logical implication between the assumptions of the argument and its conclusion. In this case, the first premise serves as a liaison between logical and causal implications, and, therefore, has great importance in a geo-historical explanation. This premise, in fact, a complex sentence, created, in a syntactic manner, from simple sentences, one of which is the conclusion. Thus it is possible to turn a complex sentence “If C occurred then E occurred” into an independent inference with a simple sentence “C occurred; therefore, E occurred”17. These sentence and argument are synthetic (as opposed to analytic), i.e. the complex sentence is not a valid logical argument, but rather extends the knowledge. In the predicate it tells what is not considered in the concept of the subject, that is, the predicate is not included in the subject. Its truth is not based solely on the law of non-contradiction and it depends not only on the meaning of its terms (or their definitions) and on its logical form. It imparts posteriori knowledge expressed in a synthetic sentence. This statement is posterior and thus derives from experience, and its truth is contingent18. In other words, causal sentences of this kind are posterior and synthetic, arise from experience, and their

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12 This claim is true for analogical arguments that go either from the cause to the outcome or from the outcome to the cause. On realism in relation to geo-historical explanations, see Engelhardt and Zimmermann (1998, p. 139–233).

13 In logic we are dealing with deductive inferences and not with causal explanations. Inferences are something in the mind (intellect) and causes are something in the physical (mechanical) world. When talking about justification we’re talking about inferences and not about physical causes.

14 Concerning the use of a variety of logical-causal arguments, see: Engelhardt and Zimmermann (1998, p. 139–233).

15 In this sense, this fact in itself can indicate the realistic faith of geologists about our ability to know the physical world around us, through the ways of judgment and reasoning in the human mind (or in the language of Kant which we’ll discuss further, using categories and pure intuitions).

16 It is worth mentioning here that not every historical explanation is an explanation based on causality and therefore logical-causal inferences aren’t always necessary. Historical explanations can be purposeful explanations dealing with the motives of people and other states of consciousness. These explanations do not require laws or causal legality (causality is descriptive, not judgmental); they are essentially normative explanations (ethical judgments, for example, more rightful, etc.) in a specific sense and are not logical. In contrast to these, in geo-history we often deal with the causes and laws because geo-historical explanations are based on the laws of physics and are described by historical events. However, in some cases in geo-history, we also deal with descriptive explanations of a given geo-historical narrative. About descriptive explanations, see footnote 109 in Kravitz (2015, p. 38).

17 During their daily work the geologists are confronted with a multitude of practical problems concerning geological causality. For example, they often claim that the same cause can have various effects (divergence) or that various causes could produce the same effect (convergence). In addition, they claim that a certain effect is sometimes caused by a combination of various causes (multiplicity). With regard to practical problems pertaining to geological causality, see Schumm (1998, p. 58–75, 95–119) and Cleftland (2013, p. 4–7).

18 The origin of the distinction between analytic and synthetic is in Kant. In order to facilitate rather than confuse the reader about Kant’s precise observations, I have simplified and clarified these concepts as far as possible. For lack of space, these concepts will not be discussed beyond what has been said here. For the purpose of a more detailed discussion of these concepts, see: Yovel (2013, p. 35–39).
veracity does not depend only on their logical form. Causal relationships expressed by these sentences can be detected only empirically or logically\textsuperscript{19}, and are, in fact, inductive generalizations, “disguised” as causal laws\textsuperscript{20}, behind which three classic metaphysical assumptions about causality are hidden: (a) any outcome necessarily has a cause (the principle of causality) (b) identical causes necessarily have identical outcomes (an actualist claim based on the principle of uniformity of nature and sometimes known as causal lawfulness) (c) the cause always precedes the outcome in time (the causal time arrow).

In my opinion, assumption (c) is the most important because it turns the conditional sentence noted above, into a historical sentence used as a covering law (Hempel’s covering law model)\textsuperscript{21} to any historical-causal explanation, without which the explanation is not possible. In other words, without this premise, a geo-historical explanation would not be possible since it deals with the most important historical feature of time, the irreversible direction - from past to future.

When the geologist in his argument, assumes that “if C occurred then E occurred”, he implicitly assumes that E can occur only after C has occurred. But if C always proceeds E in time. Although it is a metaphysical assumption of causality in the classic sense, how can it possibly be justified in order to “save” the logical-causal arguments? Why must geologists make this assumption without which a geo-historical explanation is impossible? What is the origin of this? Since we are dealing with logical arguments and sentences from the structural point of view and with causal arguments from the point of view of content, I claim that the answers to these questions obtains its empirical validity from the world of empirical phenomena surrounding us. Since the science of geology is based on physical phenomena, it must justify the use of these arguments and sentences on the basis of unidirectional physical laws irreversible in time, on which its geo-historical explanations are based. The necessity lies in the fact that geologists, as human beings, have evolved within the framework of these laws in the course of the evolution of the Earth and the animal world. In order to clarify this position I will first present examples of geo-historical explanations based on the unidirectional laws of physics, irreversible in time and implicitly based on assumption (c) as described above. Then I will try to present philosophical arguments that support this position, and enable us to discuss about a possible reduction between the physical time arrow occurring in nature and the causal arrow expressed in geo-historical explanations and in any kind of historical thinking that deals with events of the past\textsuperscript{22}.

3. Irreversible natural processes in geology and biology and relationship between them

3.1. Unidirectional geological processes, irreversible in time

From observations of geological processes occurring in the present and of signs that the geological past of the Earth has left us, geological processes, unidirectional and irreversible in time, can be identified. These processes have occurred in the distant past, and are still active in the present, thus suggesting that concealed behind them are natural laws with a specific direction from past to future, over deep geological time. On the basis of these laws, geologists are able to consider the geological past of the Earth and explain it by means of the causal arguments described above. For example, by resorting to the geo-physical model, modern geology can explain, the factors of the movement of the tectonic plates, and reconstruct the geological structure of the Earth in the distant past. According to this model, fissures or mid-oceanic ridges originated from the heat and pressure generated by the core of the Earth\textsuperscript{23} as a result of thermonuclear disintegration of radioactive foundations, such as U, Th and \textsuperscript{40}K. The heat, generated in depth, moves in the direction of the surface through convection currents. These currents, active in the asthenosphere, transport the heat in their movement upwards toward the surface, thus providing the moving force to the plates on the surface of the planet. In this process the temperature reaches more than 4000 °C. As a result, the outer core of the earth melts and creates a heat flux between approximately 3800 °C at the base and 1200 °C at the top of the shell. In the course of time, heat transfer occurs from the top of the core to the base of the crust and some of the heated material breaks through the crust into the volcanoes on the surface and the large part of the material rises to the top of the mantle and flows to the sides, where it cools down and its specific gravity increases gradually, sinks back into the mantle and so on. In the course of this process, the convection current rises under the mid-oceanic ridge, splits, and moves to both sides. As a result of this movement it drags the oceanic lithosphere, using friction in order to move the plates to both sides. Part of the current bursts out to the sea floor and when the lava cools, it turns into basalt and actually increases the surface of the ocean’s floor. As the perimeter of the Earth does not change, the growth of the sea floor in one place must be balanced by a decrease in another, or, in other words, spreading land must settle somewhere else and return to the mantle. At the other end the oceanic plate is pushed underneath and produces a subduction zone characterized by an oceanic chasm, volcanic island arches and often a marginal sea, that is, on one side of the plate a new ocean is opened and on the other side an ancient ocean closes\textsuperscript{24}. In the ocean that has been opened, among others, the activity of sedimentary rocks stratigraphy such as: clastic rocks, biogenic rocks, chemical rocks etc. begins. The stratigraphy of these sedimentary rocks occurs during geological time over basic rocks (igneous rocks) and metamorphic rocks of the crust of the Earth that are exposed on the surface surrounding most regions on the surface of the planet.

As can be seen, the simplistic explanation described above, is mainly based, consciously or unconsciously, on unidirectional laws of physics irreversible in time. The Earth, being a warm body, strives

\textsuperscript{19} As I explained above, in classical logic, conditional sentences say something about the existing relationship between the first section and the final section. They can represent different types, such as sentences in which the final section is logically implicated from the first section or from the definitions of concepts contained in the statement, and so on. Geology and other natural sciences, often use conditional sentences in which the connection between the initial and final sections is an empirical-causal relationship. In any case, it is important to understand that logically, the logical feature common to all the conditional sentences is that if the first section is true and the final section is false then the conditional sentence is false.

\textsuperscript{20} In the language of Kant it can be said that these sentences represent the category of the human mind “cause and outcome” (causality and outcomes) that is expressed in a logical form (intellectual form) under the section “relation” and form of judgment (or form of the sentence “hypothetical”). About these concepts see: Yovel (2013, p. 50, 169–175). For further details about the metaphysical assumptions of causation, see: Kravitz (2013, p. 31–32).

\textsuperscript{21} Model of explanation according to which to explain an event by reference to another event necessarily presupposes an appeal to laws or general propositions correlating events of the type to be explained with events of the type cited as its causes or conditions. For in depth details, see Hempel and Oppenheim (1948).

\textsuperscript{22} About reductionism in geology, see: Kravitz (2013, p. 33–38).

\textsuperscript{23} As known today, most of the heat inside the Earth comes from the decay of radioactive materials. However, there are, or once were, sources of additional heat caused by the gravity of the Earth (especially in the early stages of Earth’s formation), tidal forces (when the moon was closer to Earth), the friction generated by the movement of the plates and the heat radiated during crystallization of the core (Porir, 2005, p. 230–231).

\textsuperscript{24} For in depth details, see for example Stewart (1990, p. 72–123).
to cool down spontaneously so that, in general, with the exception of the process of stratigraphy of sediments and others, most of the global system described above is a “mechanism” responsible for the continuous cooling of the Earth25. By looking at these processes and cooling mechanisms and the stratigraphy process of sedimentary rocks, it is possible to identify a number of geo-physical laws with a historic and progressive characterization in time26. These processes allow geologists to make a clear distinction between geological events that have occurred in the past and those that occur in the present, and to link both of them to a cause, which always occurred in the past, while the outcome occurs in the future, and not vice versa. In general terms, these processes can be divided into three main types:

(1) Radioactive production of heat resulting from the disintegration (decay) of radioactive materials and the radiation emitted as a result.

(2) Thermodynamic activity related to cooling processes through convection currents. In fact there are three types of physical processes responsible for heat transfer: conduction, radiation and convection. The dominant process in the geo-physical model, as presented above, is convection.

(3) Stratigraphic activity of new marine sedimentary rocks.

Below is a summarized description of these processes:

(1) Radioactive production of heat in the core of the Earth, originating in the process of disintegration of radioactive materials which is asymmetric with regard to the direction of the time arrow, i.e. it is a one-way and irreversible process in time. When geologists assume a constant decay of nuclide and a uniform rate of radioactive decay, they assume asymmetry and non-reversibility of the time arrow. Radioactive nuclide breaks down spontaneously and at a known rate, from a parent radioisotope state into a daughter nuclide. The disintegration always occurs spontaneously in one direction, from an unstable state of the atom to a more stable atom. This asymmetry and irreversibility is similar, in a way, to the asymmetry of the thermodynamic time arrow, they share the same direction, from past to future, and never the other way round. It is possible to test this assumption by looking at the language and professional terms used by geologists to explain radioactive phenomena, such as half-life, the absolute age of a rock, the rate of decay, and so on. These concepts indirectly suggest that geologists assume that the geological time arrow is unidirectional; otherwise, these terms would have no meaning. If, for example, geologists had assumed that the time arrow is reversible, what would be the meaning of the term “half-life”?  

(2) The description of thermodynamic activity, related to cooling processes through convection currents, is based mainly on the laws of thermodynamics, in general and on the second law of thermodynamics, in particular27. A convention related to this activity concerns the spontaneous transfer of energy from the warm part of earth, in which radioactive production of heat occurs, to the colder part28 in correspondence with the second law of thermodynamics. This law clearly supports the evolutionary world view of geologists because it is the only law of physics that describes the progressive development of macroscopic systems in time (Kravitz, 2013, p. 26–29). The second law of thermodynamics describes the macroscopic world of nature as a world governed by an asymmetric and irreversible time arrow — in other words, is describes a series of unique events, joined to each other and developing in one direction (law of historical succession). Therefore, the majority of physical phenomena, irreversible in the time dimension, are explained by this law. In statistical mechanics, the second law of thermodynamics is a law of probability based on a basic concept in physics, that of entropy. Entropy is a measure of disorder in physical systems. The second law of thermodynamics states that in closed isolated physical systems, entropy can be maintained or can even grow in the course of time up to a point of thermodynamic equilibrium, which is the most probable final state from a statistical point of view (as an aspect of microscopic dispersion of states) in which the system can exist (a state of maximal entropy and disorder). The law enables the inference that every closed and isolated physical system has a time arrow with a clear direction, from a state of low entropy (in the past) to a state of thermodynamic equilibrium (in the future), in which the system receives the highest value that it can sustain.

(3) One of the basic principles of stratigraphy is the principle of superposition which was first articulated by Nicolas Steno (1638–1686). The principle can be formulated as follows (Kravitz, 2014, p. 692):

“In any undisturbed continuum of strata, any stratum will be younger than the stratum on which it rests, and older than the stratum that rests on it. In other words, in an undisturbed continuum of sedimentary rocks, any stratum will be younger than that on which it rests, and older than that resting on it, i.e., in a stratigraphic column, the strata of rocks are arranged according to the order of their formation — from the older (at the bottom of the column) to the younger (at the top of the column).”

From this formulation it is easy to understand that the stratigraphic process of a sedimentary rock is a one-way process irreversible in time. Steno based the principle of superposition on the law of gravity. He noticed that particles sink in fluid in quantities relative to their size and weight. The first to sink are the largest, followed gradually by the smaller ones. Changes in the size of particles cause the creation of horizontal strata or stratification. In other words, if we assume that uniformity is preserved in the laws of nature (in this case, in the law of gravity), the strata are stratified one after the other, so that in any kind of geological continuum, any given layer must be older than the layers above it, and younger than

25 This is the process of cooling itself. This does not mean that the Earth actually cools. Although the radioactive decay is the main heat source, there may be other sources not yet known to us and therefore the subject still arouses controversy and debate among geologists (Poirier, 2000, p. 230). If we assume that the only heat source is due to disintegration of radioactive materials, it is clear that today the source is due to disintegration of radioactive materials, it is clear that today the radioactive production of heat resulting from the disintegration of radioactive materials is 5.5 times smaller than the energy that Earth had 5 billion years ago.

26 Of course there are other chemical and physical processes (reversible and irreversible in time) that participate in the global process described here, but since the article is philosophical, I do not intend to go into details concerning these processes. On the one hand the processes listed above are central in the global process and on the other hand are quite easy for the average reader who is not proficient in investigative disciplines practiced in various Earth sciences, to understand.

27 Here the explanation for thermodynamic processes will be general and qualitative, but sufficient for the purposes of this article. For a detailed and quantitative explanation, see: Poirier (2000, p. 230–244).

28 As I described above, in general, there are three types of mechanisms responsible for heat transfer: conduction, radiation and convection. The most important mechanism in the geo-physical model is convection so I will put special emphasis on it. As for the rest of the heat transfer mechanisms, see Turcotte and Schubert (2002, p. 132–194, 262–282).
the past to the future, that are compatible with Darwin species of organisms normally proceeds irreversibly. This development and fauna support this claim: for example, the evolution of different usually happens when different forces operate on the same species. Biological evolution. The second branching pertains to what Darwin amount of stable molecules grew. This process resulted, among the universe gradually cooled, chemical evolution accelerated and the Earth, even before the creation of the flavors, camouflages, etc. Environmental conditions, to disease, the capacity to utilize particular reproduction and the transfer of traits to the next generations, certain features could enjoy an advantage compared to others, survive, lack this feature. That is, in certain environmental conditions, certain features could enjoy an advantage compared to others, in terms of reproduction and the transfer of traits to the next generation. Such features can be, for instance resistance to weather, to geological conditions, to disease, the capacity to utilize particular foods, camouflage, etc. Geological environmental conditions are the critical element in both causal mechanisms, and are followed by changes in climate and in the entire world of flora and fauna. Since geological environmental conditions are changing in time in accordance with unidirectional processes irreversible in time, it is likely that the mechanism of natural selection also acts as a cause within the framework of these laws.

Many examples from the field of biology and the evolution of flora and fauna support this claim: for example, the evolution of different species of organisms normally proceeds irreversibly. This development can be divided into three biological branches advancing from the past to the future, that are compatible with Darwin’s theory of evolution (Denbigh, 1989, p. 504–505). The first branching out towards the future in the organic world occurred already in ancient Earth, even before the creation of the flora and fauna. As the ancient universe gradually cooled, chemical evolution accelerated and the amount of stable molecules grew. This process resulted, among others, in the proliferation of organic molecules that resulted in biological evolution. The second branching pertains to what Darwin called divergence. Since the appearance of initial life on Earth, many branches of the new species have evolved in accordance to the mechanisms of variation and natural selection. During this process various features developed in creatures with a common origin. This usually happens when different forces operate on the same species.

The third branching toward the future occurs in every individual organism. Physiological development of an individual organism proceeds in one direction, irreversible in time, similar to the direction of the development of the entire biosphere. For example, the process of cell division in the body begins from one particular cell and proceeds in the direction of multiple cells in the adult organism.

Evolutionary development in the animal world brought about mental development of more advanced beings, first and foremost humans. Mental processes, such as the biological processes described above are also, in a sense, unidirectional and irreversible in time. The following quote and specification supports this argument in principle (Denbigh, 1989, p. 504–505):

“In higher animals there is also the irreversibility of mental processes which, as experienced in ourselves at least, is a branching of one thought into another, a branching into a blooming, buzzing array of new beliefs and intentions, new desires and emotions. Many of these mental items remain with us as an accumulation in the memory. Perception and cognition thus appear as an adding on to what is already in our minds, and not as a subtraction; for once we have seen or known something we never undergo the hypothetical reverse process of unseeing or unknowing that thing. This point was nicely illustrated by Cost de Beauregard (1963, p. 115) when he remarked on the absurdity of supposing that, having read some book, we could delete from our minds everything said in the book by the act of reading it backwards, from end to beginning! The branching which occurs in mental activity is often the making of connections—its the putting together of clues to form some new and meaningful whole in the mind. As Polanyi in particular has emphasized, once the new whole has been grasped its clues take on a different character. A nice example is provided by problem pictures such as the one shown in the Tractatus where we see an animal’s head facing to the left, and then we quickly realize that the picture also shows a different animal’s head facing to the right. Once that double meaning has been grasped we cannot withdraw that understanding and see the picture as representing one animal only. The cognition is irreversible.”

From cognitive development irreversible in time, as described above, it is reasonable to assume that the causal-logical structure of human thought has also been affected significantly by that. Thanks to this development, for example, we can legitimately refer to inductive judgment by which we intuitively implicate from the past to the future rather than the other way round. In addition, as we have seen, any historical and geo-historical explanation is logically based on the causal arrow that assumes that the cause always precedes the outcome in time, thus enabling geo-historians to assume causal laws of the kind of “if C happened then E happened” at the base of logical arguments.

If so, what was said so far can be summed up in the most schematic way, as follows: unidirectional laws, irreversible in time, control the geo-historical nature of Earth and have left their imprint on the evolution processes of the flora and fauna. As a result, creatures with a mindset that is unidirectional, irreversible in time and capable of causal implication from cause to outcome, have evolved on Earth. Out of this ability, another ability has developed, that of implicating from the outcome to the cause. In both cases, we understand that the cause precedes the outcome in time.

4. Evolution, epistemology and the relationship between them

The category of causality formulated by Kant, discussed in this paper, is one of the patterns of our minds that we impose on the impressions of the senses. That’s to say, that the fundamental laws
of nature and the basic framework of experience originate in us. Precisely because of this state of affairs they can be constant, necessary and universal since the sensations and sensing impressions are fragmented and constantly changing, whereas the mind has fixed patterns without which we cannot perceive the world and create science. These are general patterns into which the sensual impressions enter. They are, in fact, the basic concepts (categories) of the mind, that establish and stabilize experience and nature. Without these concepts, we cannot explain any coherent experience and the science in which scientists work.

Unlike Kant’s approach, I would argue that there cannot really be a separation between human knowledge and the world of nature, because the human mind, as I have shown above, operates within the framework of the human brain that had evolved as part of the natural world (natural fauna) in the course of evolution and through the mechanisms of natural selection. Therefore, the concepts (categories) of the mind and the forms of perception (space and time), can only be experimental because the process of the development of the brain and the mind over time through natural selection, is an experimental process in every respect – whatever survives this experience endures and whatever does not – is completely or partially extinct. This is how an adjustment between the concepts of the mind and the outside world, which is subject to impressions of the mind is created. My claim is empiricist in the broader sense. Both the concepts and sensory impressions of our mind originate in the experimental world. Man is not born a tabula rasa – the experimental knowledge has accumulated in the course of the evolution of the brain and leaves an impression in his mind. Hence the validity of the laws of nature – under which the mind developed, and that’s its reflection on what happens in the world. In other words, the laws of nature and the categories are immanently “seared” in the genome of the human brain and in our mind. From our perspective they appear a priori but in fact the concepts of the mind are a posteriori in the broad sense of learning from the experience of evolution. I agree with Kant’s argument that thanks to them our daily experience is possible, but only within the framework of the learned concepts and sensations accumulated from the long experience of evolution.

In other words, I argue that no one can have a priori but only a posteriori knowledge. Any knowledge is a posteriori in a particular context and meaning. Even the categories and the forms of the mind, are “templates” of the mind built as developmental functions of the human brain in the course of evolution. These “templates” are actually preserving the accumulated experience during their formation in certain environmental conditions. The logic of thinking itself is a logic based on experience concepts and in fact the analytical claims, in their form and content, originate from accumulated experience during human evolution. In other words, analytic claims, contrary to what many people think, do not depend only on the meaning of the expressions that appear in them. The experience is inherent in these expressions by virtue of evolution that shaped them during a long time and so if we deny analytic claims or deductive arguments, we do not necessarily receive a logical contradiction. In other words, these claims and arguments are not necessarily true. Sometimes if language or logic is replaced, the contradiction may disappear. In this sense, I support the naturalistic position. I believe that humanity is part of nature and all the laws of nature that apply to other beings and are objects in nature, apply to it as well. In accordance with the theory of evolution, the creation of Humans took a long time in the course of which the experience was impressed in the “templates” of the mind and its forms of perception. These “a priori” patterns (“templates”) of thought are growing during the processes of evolution, as described above, and are affected by the development of the geology and the flora and fauna of the earth in a direct and necessary way. Our ability to invent and learn a language is due to the structure of these templates. The logical and the natural language sentences were formed unconsciously on the basis of the inherent evolutionary experience impressed in the mind’s categories and hence they can never be analytical - a priori or synthetic a priori, as Kant thought. This claim is supported and well illustrated by the following quote (Campbell, 1974, p. 441):

“Though we reject Kant’s claims of a necessary a priori validity for the categories, we can in evolutionary perspective regard the categories as highly edited, much tested presumptions, “validated” only as scientific truth is validated - synthetica posteriori from the point of view of species-history, synthetic and in several ways a priori (but not in terms of necessary validity) from the point of view of an individual organism.”

Nature established the experience as absolutely necessary and therefore probably the causal connection is also necessary. As described before, the causal necessity and the causal time arrow are products of the unidirectional and irreversible in time processes and natural laws, within which and by which the human mind has evolved. This mind has evolved so that if it understands the essence of the cause, immediately, it is able to see that the outcome is the result of a logical implication, from it (cause). Just as the sum of the angles is logically implicated from the polygon shape. Nature itself determines the necessity so the human mind which evolved inside it and from it, developed the necessary “templates” appropriate to nature’s laws which apparently operated and still operate in the course of the evolutionary development of the mind. We come into this world with these “templates” and innate expectations that enables the learning process. These “templates” work as instincts and sometimes we are not even aware of them. By this naturalistic approach, causal inference is carried out as part of the instinctive functioning and according to innate “templates” that were impressed on us in a natural way, during the evolutionary development of the human mind. This approach is supported by a branch of the philosophy of science known as “evolutionary epistemology”.

This epistemology was developed by Lorenz Konrad (1903–1989) and others and is, in a sense, a kind of interpretation and increment of Kant’s epistemology. This interpretation is known in the philosophical literature as EEM (Bradie and Harms, 2015) and in fact is based on the integration of the teachings of Kant with Darwin’s theory of evolution. According to this interpretation, a priori concepts or categories, such as space, time, causality, etc., are part of our thinking and perception mechanism which is the product of biological evolution that helps a person to survive in his environment. The following quotation clarifies the matter (Evans, 1975, p. 188–191):

“Just as the form of the fish is given a priori, prior to any individual coping of the young fish with the water, and just as it is this form that makes this coping possible; so it is also the case with our forms of perception and categories in their relationship to our coping with the real external word by means of experience ………

Rather, all our forms of intuition and categories are thoroughly natural. Like every other organ, they are evolutionarily developed receptacles for the reception and retroactive utilization of those lawful consequences of the thing-in-itself with which we have to cope if we want to remain alive and preserve our species.”
Based on this interpretation it can be said that the patterns and categories of the mind are indeed “a priori” for the individual person who was born equipped with genetic information containing these patterns, but by being a product of evolution and from the experience of the person in his environment, he accumulates in them all the phyletic experience of the human species and the biological species that preceded it. In this sense they are not absolute — a priori — as Kant thought. This approach argues, indirectly, that there is a possibility in principle to make a reduction between the laws of evolutionary biology, the cognitive laws and the laws of logic. In recent years this reducibility thesis was formulated more radically and states that classical laws of logic can be derived directly from the theory of evolution. It can be said in terms of reduction that logic is reducible to evolutionary theory and logical law comes directly from evolutionary law (Cooper, 2001, p. 2–5). That is, there are no laws of logic that are separated from the laws of evolution. All the laws of logic can be explained and described with concepts from the field of evolutionary biology. The following quotation clarifies and supports this claim (Cooper, 2001, p. 17):

“That this is possible is a hypothesis called here the Reducibility Thesis. It states that the laws of logic, or at least of classical logic and certain generalizations of it, are reducible to evolutionary biology in a standard sense: The terms of the logical are definable in evolutionary terms and logical assertions are deducible from evolutionary assertions.

If the Reducibility Thesis has merit, the principles of rationality are so deeply embedded in evolutionary theory that their foundations cannot rigorously be investigated independently of it.”

In the present article I attempt to support this claim and to extend it into the field of geology. As mentioned above, evolution of the flora and fauna is directly affected by the geological evolution of Earth. Therefore, if we assume that categories of the mind and laws of logic can be reduced to the laws of biology, this implies the possibility to reduce the laws of logic to the laws of geology. Examples cited in this article integrating laws of logic with physical laws that describe geological processes and phenomena, support this claim.

Hume noted two significant characteristics of the causal relationship: the proximity and the preceding of the cause to the outcome in time. In the present article I would like to emphasize the last characteristic because it expresses the unidirectional nature of the causal chain. Otherwise, what happens in the present would not necessarily reflect what has really happened in the past. More specifically, without the unidirectional causality, causal chains lasting for a long-term could not have been formed and time would mean nothing and would have been left without a history. As I have shown above, the necessity of the causal connection probably lies in the unidirectional laws of nature, such as the second law of thermodynamics, the laws of radiation, radioactivity etc. Even the laws of biological evolution are characterized by a unidirectional feature irreversible in time, that has become impressed in the human mind and determined its structure.

If so, the general laws of nature express general causal links and justify specific causal links. In other words, we could reasonably assume that the category of causality was derived from general unidirectional laws, by which the mind can justify and understand the specific causal links that we encounter in science and in everyday life. The following quote explains and supports this argument, in a certain sense (Evans, 1975, p. 211):

“Since we are today ignorant of its physiological foundations, we can examine the category of causality only through critical epistemology. In its biological function, it is an organ for comprehending the same natural lawfulness aimed at by the disposition to acquire conditioned reflexes. We cannot define the concept of cause and effect in any other way than by determining that the effect receives energy from the cause in some form or other. The essence of propter hoc which alone differentiates it qualitatively from a uniform post hoc lies in the fact that cause and effect are successive links in the infinite chain of phenomenal forms that energy assumes in the course of its everlasting existence.”

Forms of causal-logical structures in geo-historical explanations, as described in the beginning of the article, justify this claim in a way. In these structures, the description of an event should be obtained from the laws and the descriptions of the circumstances in which the event occurred. According to this concept, we are entitled to resort to the causal argument after we have built a scientific explanation for an event. The events or conditions, described in the premises of this explanation, are the causes, and events described in the conclusion, are the outcome. According to this view, the cause and the outcome are events linked by a law with a basic structure “if C will occur then E will also occur” and in it the unidirectional causal time arrow, irreversible in time, is immanently impressed.

I assume that causality indeed exists in nature and is expressed through the laws of nature. In the case of geo-history, causality originates from the asymmetric, unidirectional laws of nature in which the cause always precedes the outcome, and it is expressed in geo-historical explanations using logical arguments in which the first argument is the logical-causal sentence “If C occurs then E also occurs”. In this sense, as in the philosophy of Leibniz, I maintain that the truths of our minds reflect the world, but in order to use such an argument, we should assume that a harmony of all things with all things, exists. This assumption can have a significant justification based of the assumption that man evolved as an integral part of nature and, therefore, when he enacts the laws of nature through categories of the mind and certain sensual perceptions which are themselves a product of nature, harmony exists between man and nature. In an epistemological and mental respect, this harmony is expressed through adjustment of all ideas with all of the objective situations expressed by them. The one who is responsible for this harmony, according to Leibniz, is God and I am transferring this responsibility to the process of evolution connecting the development of nature in the inanimate world (geological world) and the development of flora and fauna (evolution), in which emotions, sensory mechanisms that operate the senses, wisdom and the categories of the mind, evolved.

5. Discussion and conclusions

In this article, I claim that the origins of categories and forms of perception derive from the evolutionary experience acquired by the human biology over time. They were created from this experience and therefore can apply only to objects suitable to the conditions of experience. For example, we must assume the law of causality in order to facilitate the transition from the subjective sensations to the objective world. From a formal logical aspect this law is not necessary, but without it any experience would be impossible. This structure is made possible by assuming that the laws of causality arrange the events according to the direction of their progress in time. We assume a priori, that there is a rule that determines the objective order of events in time. This rule allows us to go from the order of sensations to the order of events themselves. If we had not assumed a rule according to which the outcome follows the cause.
in the objective world of the events, we would have no right to interpret the subjective order by an objective order. As I have tried to show throughout the article, this rule originates in the evolutionary processes that significantly influence our way of thinking. Evolutionary development of geological and biological processes in time, imprints the causality law in the human mind which has developed within the framework of those laws allowing us to organize events in one objective time during which mankind has evolved.

Moreover, the “objectivation”30 process through categories and sensual perceptions, does not apply only to external objects, but to mental events as well (Bergmann, 1972, p. 132). The consolidation of mental experiences into a unified unit is an “objectivation” construction just like the construction of cells or atoms in biology or in physics. For this consolidation, we need an objective background, the background of time, which we use in order to determine objective mental events, just as we use space and time together, to determine physical objects. In this sense a certain similarity exists between emotional events and events that occur in the physical world and that alone could indicate a unity in the laws of nature in which the human mind evolved, and that there is no substantial difference between assuming the arrow of time to explain mental events and assuming it to explain physical events. In this sense, thought builds the emotional and physical objects by laws which are supposedly determined by it within the capacities of the mind itself. I maintain that these capacities have evolved in the course of the evolutionary history of the mind. It follows that the mind theoretically assumes time a priori before any experience, but actually time have been before the mind and what remained to be develop for the mind was in the domain of the mind, and not the other way round, as claimed by Kant. In other words, unlike Kant, my position is that the mind is not a condition (prerequisite) for experience, but rather that experience is the condition (prerequisite) for the mind. This is the reason why apparently every physical or psychological object is subjected to categories and sensual perceptions, but the truth is, that the correct term is not “subjected” but rather there is a match between the actual natural laws existing in nature and the categories derived from the human mind that has evolved under the same laws. Therefore we can conclude that only an object suitable to the prerequisite, can appear possible to us. Other possibilities do not exist for a mind that has developed in the frame of experience and causal laws that determine the objective order of events in time.

If we assume that the external thing (experience) is totally foreign to awareness and consciousness, how then are we able to explain why it is still subject to their prerequisites? The answer can be found as a result of our assuming the existence of the evolutionary world as described in the teachings of Darwin. We are creatures that develop in the developing world, hence the correlation between our cognition and consciousness, and the real world. Therefore the external world and experience is no stranger to awareness and cognition, because consciousness is subjected to the outside world rather than the outside world – to consciousness, as Kant thought. Kant’s transcendental proof reveals the prerequisites of experience, but cannot answer the question: Why is the independent external world subjected to the conditions of our experience? The sensations themselves, offer us the raw material for mental activities, obtained in the course of human evolution, design of shape, allowing them to match the requirements of the mind which is itself the product of that evolution. In other words, categories as ways of judgment, like sensual perception, are physiological brain functions and that, perhaps, explains their logical a priori validity. Space, time and causality are pre-prepared in our minds just as the vision is pre-prepared in our optic nerve. The a priori validity of these ways of judgment and sensual perceptions, is due to our inherent ability in a physiological-evolutionary sense. If so, adjusting the world to the mind is merely adjusting the mind to the world that is the creation of nature. The world is translucent and comprehensible to humans, because man himself is only the essence of the world, containing all the elements that make up the world in his being. The consciousness and awareness of the mind are a creation of the human brain, which itself is a creation of nature. Categories of our minds and sensual perceptions are actually functions created for survival, formed through evolutionary experience and chosen during the struggle for existence, because they were the most adapted to reality. In other words, the human race has acquired the categories and sensual perceptions by adaptation to reality. These were the ones that fit the world, its laws and therefore they were preserved and inherited, while other mental tools that did not fit the reality of the world were destroyed and lost (Bergmann, 1972, p. 181).

The purpose of this article was to show, through the explanations, on the basis of fundamental assumptions and scientific observations from the field of geology and biology, how is it possible to argue that the human mind and its tools of logic, originated from the processes of nature and not necessarily established these laws, but rather adapted them to the environment in which they evolved over thousands of years of evolution. Such a claim, if justified, could support the claim that nature, in general, and human nature, in particular, imply that, in principle, there is a possibility to derive the causal time arrow out of the number of physical arrows of time that exist in nature, and appear to us to be unidirectional and irreversible phenomena. Of course, such a reductionist claim needs many other justifications and I leave those to further research.

References

30 The objectivation process is the operation of constructing a unified and constant object from a multitude of sensations. It connects different emotions to a permanent connection and holds the connection created in this way despite the changes inside the feelings, and the changes occurring in the things themselves. In this process the object is being created in our minds out of the connection of many impressions. In order to isolate an object and to hold it in its identity in this proliferation, we have to go through a multiplicity of sensations, assemble and highlight them as a single unit in front of other impressions of the environment. For further details, see: Bergmann (1972, p. 119–145).

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