A theory of planetary evolution

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Abstract Ever since the time of Darwin, evolution has remained a hot scientific topic. Darwin held a multiple-mechanism view of biological evolution. Some modern-day physicists have addressed physical phenomena in the universe, including stellar evolution, while the interests of some have even overlapped with biological evolution. In this tradition, we propose the discovery of a new law for planetary evolution. Here we show that *the logic of achievement* is a natural law for planetary evolution. We name this new law in this context *the law of strata*. Planetary evolution refers to the potential evolution into being on celestial bodies such as planets, asteroids, and satellites. After outlining planetary evolution by natural law, we address its implications for our world's place in the universe, natural ethics, scientific progress in elementary particle physics, biological evolution, ecology, neuroscience, and finally, the global challenges of sustainability. **However, we dismiss *the theory of planetary evolution* as unscientific, and it is a *lengthy, untenable* theory of the mesocosmos, with *indefensible* concepts, logic, implications, and conclusions. The theory of planetary evolution is a false theory of the mesocosmos developed earlier than the true one in the literature and in viXra, which we suggest examining before studying this paper, and serves only as one source for enabling a comparison between two theories of the mesocosmos and for facilitating the discovery of the mesocosmos.**

Keywords Evolution, Law of strata, Logic of achievement, The mesocosmos, Theory of planetary evolution

1 Introduction

Evolution has gained scientific importance ever since Charles Darwin published *The Origin of Species* in 1859. Even today, scientific research on evolution is very active[1-5]. Although Darwin held the belief that virtually all evolutionary change is the product of natural selection, he did not mean that natural selection is the exclusive means of modification[6]. The 1930s and early 1940s brought a synthetic view to evolution, adding the engine of genetic mutation to the Darwinian theory of natural selection[7,8]. Its close connection to Darwinism explains why this modern theory came to be called Neo-Darwinism or, just as often, the Modern Synthesis[7,8] (MS). Recently, proponents of a broader framework, termed the extended evolutionary synthesis[9] (EES), have sought to weave other drivers of evolution, such as developmental bias and plasticity, into the very fabric of evolutionary theory. While supporters hold that such influences cannot be reduced to genetic phenomena as in the MS, not all researchers believe that evolutionary theory needs such a rethink.

Whereas biologists research biological evolution, physicists usually address physical phenomena in the universe[10,11], including stellar evolution[12,13]. Within physics lies mechanics, which seeks to explain the way things work in terms of energy, forces, and motion. One of these 'things' is stars: on a universal scale, stars are essentially bodies of plasma, and the atoms that comprise planets are born in defunct stars. Some physicists are also interested in how planets are formed and what materials they are made of[14]. Still others are interested in biology and biological evolution. For example, Schrödinger[15] believed that living matter is likely to involve laws of physics hitherto unknown, and that these laws, once revealed, would form an essential part of all natural laws in the universe. Feynman[16] expressed that the fact that humans are able to do so many more things than animals can apparently do is remarkable and mysterious, but he wanted to investigate evolution by himself without immersing himself in the existing theories.

In the light of the above, one might now pose the questions: Are current theories of evolution still incomplete? In particular, does planetary evolution require any new natural laws to account for its processes? Our answer to these is a resounding yes. Planetary evolution is undoubtedly a deep question, and new natural laws surrounding it remain to be discovered. In the autumn of 2003, a colleague of ours posed the following question: Why was Einstein more intelligent than an ape? This question has since led us to an important discovery about planetary evolution. Few know that the worldviews of some current scientific teachings, such as elementary particle physics[17] and Darwinian evolutionary theory[6,8], do not acknowledge humanity's important place in the universe and our important existence on Earth. Planetary evolution by natural law can restore our place and our existence to their fairly intuitive nature and rightful importance. Here we share with the reader our discovery about planetary evolution.

2 The logic of achievement as a candidate for a natural law

According to Feynman[18], the first step in looking for a new natural law is to first guess it. What a wonderful world that is populated with living creatures! But planetary evolution must take our planet and all other planets in the universe into account: therefore, it should refer to the potential evolution into being, rather than referring uniquely to the evolution of life on our planet as we presently know it. With this rational view of the challenge faced by any account of planetary evolution, our initial guess for a natural law governing it is *the logic of achievement.* In the spring of 2003, we read Polanyi's *Personal knowledge*[19] and *The Tacit Dimension*[20]. An idea originating from Polanyi[19,20] and modified by us in this paper, the logic of achievement can be described as follows: (1) A success/failure system has an n-level structure ($n \geq 2$), with each level having its own operations or operational principles; (2) Dependency relations between any two consecutive levels exist, whereby the lower level includes the conditions for success, as well as the causes of failure, of the upper level. Below is an outline of our initial hypothesis of a hitherto unknown law for planetary evolution (Fig. 1).

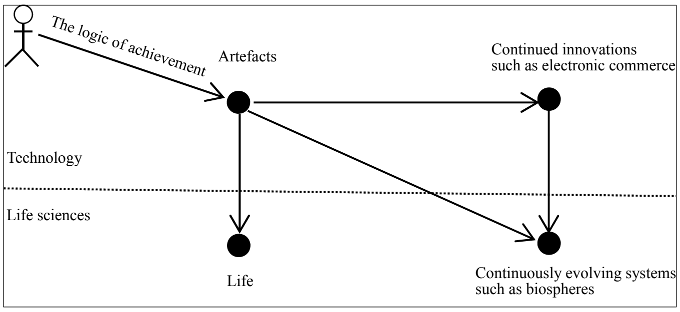

Figure 1 | Initial hypothesis of a hitherto unknown law for planetary evolution. We initially hypothesize that the logic of achievement can serve as a natural law for planetary evolution. First, artefacts obey the law of achievement. Second, continued innovations in modern times, such as electronic commerce, also follow the logic of achievement. Then, it is within reason to conclude by generalization that like technology, the life sciences (that is, life and continuously evolving systems such as biospheres) also obey the logic of achievement.

Nothing is an artefact unless it serves a useful purpose[19]. However, to serve a purpose, an artefact must have an integrative whole that exists separately from its individual parts to perform some functions, in the execution of which it can succeed or fail. In the Stone Age, for example, people shaped stones into a variety of cutting tools. Stones must have proper hardness to be useful; however, stones likewise require a suitable shape to serve their cutting function. Hardness is a condition for success, as well as a cause of failure, of shape. Thus, stone-made cutting tools have a two-level structure following *the logic of achievement*[19]. Such a two-level structure can be seen to operate in many sorts of artefacts. For example, the playing of a game of chess is controlled by principles that rely on the observance of the rules of chess, but it is the strategy of the players that controls the game, and these strategies cannot be derived only from the rules of chess[20]. The giving of a speech can be seen to have a five-level structure[20]: namely, the production (1) of voice, (2) of words, (3) of sentences, (4) of style, and (5) of literary composition. Each of these levels is subject to its own laws.

Readers of modern sensibilities can likewise easily observe that the continued innovations of today such as electronic commerce also follow the logic of achievement. Kalakota and Whinston[21] provided a generic framework for electronic commerce, which has a four-level structure: network infrastructure, multimedia content and network publishing infrastructure, messaging and information distribution infrastructure, and common business services infrastructure. On top of this four-level structure, we can build electronic commerce applications gradually, which may be layered in a similar fashion.

In concluding the above, technology (which includes artefacts as well as modern-day innovations), as part of the universe, must obey natural laws, discovered and undiscovered. We have discovered that technology obeys the logic of achievement, which we propose as a novel law. To reason further, living organisms are organized functions only to the extent to which they sustain life[19]. Biospheres, which are global ecological systems, have the problem of sustainability. Hence, all forms of life and biospheres are success/failure systems. By generalization, it is within reason to conclude that, like technology, life sciences (that is, life and continuously evolving systems such as biospheres) also obey the logic of achievement. As a natural law, the logic of achievement for technology is intuitive and unlikely to provoke controversy. Applying the logic of achievement to the life sciences, as we will do next, is not so simple, but perhaps the discussion will refine our understanding of the logic of achievement so that we can appreciate its importance as a natural law for planetary evolution, as shown subsequently.

3 Observations of the logic of achievement on Earth

3.1 Animals

We can apply the logic of achievement to animals to create a two-level structure (Fig. 2a). The operational principle of the lower level is called *bodily experiences*; that of the upper level is called *meaning*[20]. Although humans have a three-level structure (Fig. 2b), they share these two levels in common with animals. Dependency relations exist between the two levels. In principle, animals must have all bodily experiences to operate successfully: experiences are the basis on which animals judge meaning, and to do so accurately is essential to continue living. On the contrary, impaired bodily experiences, such as poor eyesight, constitute the aforementioned causes of failure, in this case to an animal's interpretation of its experiences, which can jeopardize its safety and indeed its life.

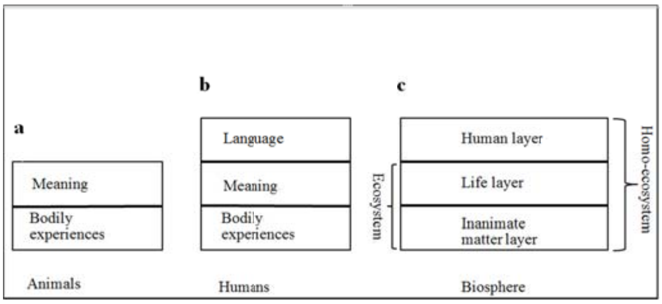

Figure 2 | Observations on Earth. a, Animals have a two-level structure. **b,** Humans have a three-level structure. **c,** The biosphere has a three-level structure, in which the homo-ecosystem consists of all three layers and the ecosystem consists of only the two lower layers.

Animals experience the outer world with their bodies through sense organs: eyes, ears, etc. There is no way in which to understand the world without first detecting it through the radar-net of our five senses. When we read *A Natural History of the Senses*[22], we are amazed by the rich variety of ways that living creatures experience the outer world, by their multi-modal capabilities of perceiving it, and the wealth of stimuli that the world presents.

For example, animals that hear high frequencies better than we do—such as bats and dolphins—seem to 'see' richly with their ears, hearing geographically, but for humans, the eyes are still the great monopolists of the senses. The human eye views an apple as red; other animals may see it in black and white. In another modality, while our skin serves an important role by standing between us and the world, it is most intimately associated with the sense of touch. The human hand moves with a complex precision that is inimitable, and it feels with a delicate intuition that is indefinable. Yet, animals are the real touch masters: sponges for instance have a profound sense of touch, and they feel every quiver in the water. Our sense of smell can be extraordinarily precise, yet it is almost impossible to describe how something smells to someone who has not smelled it. Animals would not be able to live long without pheromones because they could not mark their territories or choose receptive, fertile mates. Taste is largely social for humans. We can taste something only when it begins to dissolve, and we cannot do that without saliva.

Regardless of the presence or absence of appetite or reproductive drive, there is an urge from which no fully awake animal, whether predator or prey, is free[19]. This urge can be described as a readiness to perceive and to act, or more generally speaking, to make sense of its own situation, both intellectually (such as judging safety or danger), and practically (such as chasing or escaping). Animals' lives are sustained by the operations of yet a two-level structure (Fig. 2a).

3.2 Humans

What is the difference between animals and humans? The answer is commonly understood among biologists[7,8,23] and linguists[24] to be language. The identity of the ingredient that catalysed the Great Leap Forward can only have one plausible answer: the anatomical trait that allowed complex spoken language[23]. A semantics-based mind and culture are the defining traits of the human species[7]. In contrast, language does not exist among animals. To be sure, many species have elaborate vocal communication systems, but these consist of the exchange of signals: there is no syntax, no grammar[8]. We belong to a species with a remarkable ability: the ability to use language to shape events in peers' brains with exquisite precision[24].

Assuming that the difference between animals and humans is language, humans have a three-level structure, the topmost of which is the language layer, following the logic of achievement (Fig. 2b). Clearly, dependency relations exist among these three levels. Animals do not have any language: their meaning is limited to the inexpressible, and they can only reorganize their thoughts mentally. Because humans have oral and written language, they have the additional option of reorganizing their thoughts externally. Furthermore, humans can sustain complex thought and reason formally in sequence. Thanks to language, humans not only have an intellectual advantage over animals, but also lead an articulate social and cultural life to which no speechless being has access[19]. Moreover, language permits our thoughts to transcend time, by which animals are held captive.

3.3 The biosphere

The biosphere of our planet is a global ecological system that can succeed or fail to sustain itself. It has a three-level structure (Fig. 2c): the inanimate matter layer, the life layer, and the human layer. We term the two-level structure consisting of the inanimate matter layer and the life layer as "the ecosystem". We give the whole structure a new term: "the homo-ecosystem".

In the last passage of *The Origin of Species,* Darwin contrasted the flux of organic development with the immutability of such physical laws as gravitaion[25]. He knew well that, in terms of our two-level structure, the life layer relies on the inanimate matter layer in order to operate successfully. Furthermore, Darwin discovered the operational principles of the life layer: biological evolution by natural selection. At the time of Darwin, humans did not perceive any ecological problems in the world. Yet since that time, the biosphere has continuously evolved, and we face an ecological problem in the present day. Ecologists tell us that in the past, in the absence of human disturbance, the ecosystem eventually righted its balance and sustained itself through such challenges[26]. The above observations support the notion that, according to the logic of achievement, Earth's biosphere is a homo-ecosystem with a three-level structure. Clearly, dependency relations exist among these three levels.

Several mass extinctions have punctuated the evolution of our planet during the past 600 million years[25]. At these times, the biosphere had been an ecosystem without humans. Gould[25] once criticized the Darwinian theory of evolution's inability to explain the Permian extinction and the late Cretaceous extinction. Indeed, the logic of achievement can explain the two mass extinctions, by framing the ecosystem as a two-level, success/failure system. The inanimate matter layer constituted the conditions for success of the life layer: once these conditions disappeared, the same layer became the causes of failure of the life layer. The logic of achievement provides an explanation for the two mass extinctions in terms of natural law, a theoretical one to complement the following standard empirical explanation.

The major cause for the Permian extinction was a coalescence of continents that drastically reduced the area of shallow seas. Another cause was a drop in sea level which reduced the area of habitable continental shelf[25]. The cause for the late Cretaceous extinction, famous for wiping out the dinosaurs, was almost surely the consequence of an asteroid impact and the climatic and other environmental changes it caused[8].

4 The law of strata as a proposed natural law

Thus far, we have posited an initial guess for the law that governs planetary evolution: the logic of achievement. We have also provided observations of phenomena on Earth as examples of its explanatory power: animals, humans, and the biosphere. Now, we aim to demonstrate that the logic of achievement is a natural law. What is the scope of its logical validity? Surely it covers success/failure systems. Newton's law of gravitation has been called "the greatest generalization achieved by the human mind". He already knew of the force holding us on Earth, so he proposed it as a universal force, whereby everything pulls everything else[27]. In a similar way, we have relied on generalization to conclude that the logic of achievement applies equally suitably to technology and the life sciences (Fig. 1), social sciences, and humanities. An example in social sciences is business organizations, which are also success/failure systems that obey the logic of achievement. Another example in humanities is the historical chronicles of Chinese dynasties, which were successive success/failure systems. All living creatures have a two-level structure that follows the logic of achievement, although the interdependencies of the levels vary in sophistication. In short, the logic of achievement is ubiquitous, applicable on our planet and indeed universal across all planets.

Weinberg[17] considered that a natural law or theory must (1) offer a simplicity of ideas; (2) induce a sense of logical inevitability; and (3) be so parsimonious that there is no way to even slightly modify it without the theory leading to logical absurdities. We thus must judge the description of the logic of achievement presented above to confirm whether it is simple, logically inevitable, and parsimonious without inducing logical absurdities. First, the description is simple in that it states its logic briefly and completely. Second, a success/failure system must have an integrative whole that is separate from the operational principles of its individual levels, such as an n-level structure where $n \geq 2$ is necessitated. Third, dependency relations between any two consecutive levels—that is, whereby the lower level includes the conditions for success, as well as the causes of failure, of the upper level—are logically inevitable, and cannot be reversed somewhere arbitrarily without causing logical absurdities. In conclusion, we judge that the logic of achievement is a natural law.

We can also refer to Feynman's teachings to understand what constitutes a natural law[18,27]. Feynman[18] proposed the following steps: (1) Hypothesize a law; (2) Determine or calculate the consequences of that hypothesis to see what would be implied if this presumed law were correct; (3) Compare the results of the calculations directly with natural observations, by means of experiments or experiences, to see if they match; (4) If the predictions disagree with the observed data, the law is wrong. The strengths of the above discovery process in the field of elementary particle physics aside, we consider it ill-suited for sciences of complexity (in a literal sense), such as life sciences. Animals and humans are complex neural systems. Likewise, a biosphere is a complex ecosystem, even without taking into account its continuously evolving nature. In sciences of complexity, one often has to be content with a qualitative understanding instead of an exact calculation[28]. Furthermore, even the most carefully checked experiment or detailed observation is still a product of human behaviour: this is in contrast to logic, which is unbiased and reflects the impersonal quality of nature itself[17]. The logic of achievement is such an unbiased case, and we have argued that it is a natural law in the above paragraph.

Since Newton, the great success of his law of gravitation has given hope that other natural phenomena might also be governed by beautifully simple laws[18]. As a natural law, the logic of achievement has led us to conclude that our biosphere is a homo-ecosystem with a three-level structure and associated dependency relations. This conclusion may elicit surprise from the general public, and even from some famous scientists such as Schrödinger[15], Weinberg[29], Gould[6], and Mayr[8], who have expressed concerns about the difficulty of achieving a scientific understanding of the biosphere.

We name the logic of achievement in the context of a natural law *the law of strata*. What is the scope, then, of this natural law? As we have provided examples of observations from the life sciences and the biosphere, the reader might assume that the law of strata is a biological law, but this is an unnecessary constraint. All things, including lifeforms and biospheres, are made of atoms[27]. All ordinary phenomena can be explained in terms of the actions and the motions of particles[18]. Humanity's division of the universe into domains－such as physics, biology, geology, astronomy, and so on－is a convenience to facilitate study, not a necessary classification from the standpoint of impartial nature[27]. So, since biology is a physical phenomenon, the law of strata should also hold as a natural law for macroscopic physics and chemistry[15,29].

5 Applications of the law of strata to planetary evolution

Finally, we need to show that the law of strata (i.e. the logic of achievement) is a natural law, even an important one, for planetary evolution. Life and biospheres are success/failure systems. A biosphere consisting of one planet evolves continuously. Once it comes into being, a biosphere becomes a success/failure system with a two-level structure. Its life layer comes to rely on its inanimate matter layer in order to operate successfully. The logic of achievement provides context to nature's mysteries and life's secrets. A biosphere, like that of our planet, may evolve towards a higher-level structure, depending on the chain of events that conditions for success or causes of failure catalyse. As these events transpire, many forms of life (and even intelligence) come and go accordingly. Life and intelligence follow the logic of achievement as well, with varying sophistication.

However, a barren biosphere is without life. The logic of achievement does not apply to a barren biosphere, which evolves, but has no notion of success/failure, and where life does not exist yet (like our planet billions of years ago) or never appears. We may say that a barren biosphere has a one-level structure ($n = 1$): this level corresponds to the inanimate matter layer, the material basis for planetary evolution. In short, the logic of achievement (or its lack by extension) comprehensively accounts for the potential evolution into being on all planets.

In sciences of complexity, including planetary evolution, the logic of achievement is a clear, simple law that clarifies nature's mysteries and life's secrets, completely accounts for the potential evolution into being, and can be generalized to all planets. We conclude that the logic of achievement is an important natural law that governs planetary evolution. As far as we know, no one has solved the problem of planetary evolution in the literature, or even as much as recognized it.

6 Mathematical expression of the law of strata

Scientists communicate science with language and mathematics. Often, nature follows mathematically simple laws. Mathematics is a language plus reasoning, or a language plus logic[18]. Indeed, the law of strata can be expressed as a mathematically simple law (Fig. 3). Mathematically speaking, the law of strata is a partial ordering[30], with some qualifications. Because a success/failure system must have an integrative whole apart from its constituent operational principles, the key to reflecting and expressing such a system in mathematical form is always to hold oneness on the upper level: that is, to only assign one-to-one or many-to-one relations between two consecutive levels when looking upward. Fig. 3 shows only two examples of partial ordering: a linear ordering and a binary tree. Fig. 2a, b, and c are expressed as a linear ordering, respectively, which is the simplest model since it only consists of one-to-one relations.

A partial ordering represents an n-level structure with dependency relations very well. In particular, it can represent dependency relations with such properties as reflexivity, antisymmetry, and transitivity relations. In reality, we can say that the human layer includes its own conditions for success as well as its own causes of failure (Fig. 2c). This is the property of reflexivity[30]. While the inanimate matter layer holds the conditions for success and causes of failure of the life layer (Fig. 2c), the reverse is not true. This directionality is a consequence of the property of antisymmetry[30]. Finally, the bottommost, inanimate matter layer includes the conditions for success and causes of failure of the topmost, human layer, even though theses layers are not adjacent (Fig. 2c). This relation is due to the property of transitivity[30]. Mathematicians like to make their reasoning as general as possible[18]. In this tradition, this partial ordering with three relational properties imposes rigidity on the law of strata, thus further confirming that the law of strata is logically inevitable, and without logical absurdities. This reaffirms our argument that the law of strata, a law governing planetary evolution, is indeed a natural law.

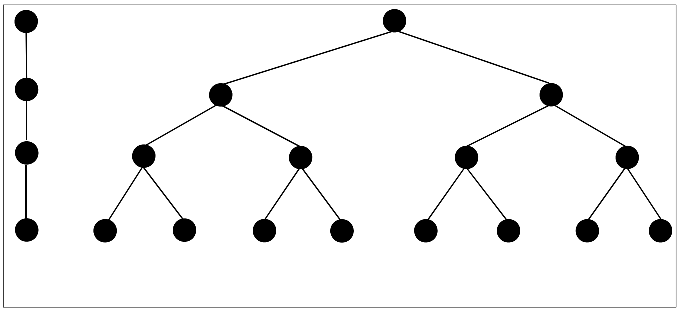

Figure 3 | The law of strata for planetary evolution in mathematical form. Legend: ● operational principles; ——— dependency relations. A relation R on a set S is a partial ordering if it is reflexive, antisymmetric, and transitive. (1) A relation R on a set S is called *reflexive* if $(a, a) \in R$ for every element $a \in S$. (2) A relation R on a set S such that for all $a, b \in S$, if $(a, b) \in R$ and $(b, a) \in R$, then $a = b$ is called *antisymmetric*. (3) A relation R on a set S is called *transitive* if whenever $(a, b) \in R$ and $(b, c) \in R$, then $(a, c) \in R$, for all $a, b, c \in S$. A Hasse diagram is a pictorial representation of a partial ordering, where the elements of a set are represented as vertices and the relations on the set are represented as lines connecting related vertices. These relations include some deductions from the reflexive and transitive properties of a partial ordering. Mathematically speaking, the law of strata is a partial ordering. In the law of strata, dependency relations—consisting of both conditions for success and causes of failure—within the set of all operational principles comprise the partial ordering. This figure shows two examples of partial ordering: a linear ordering and a binary tree.

7 Implications

Planetary evolution is a “missing link” between stellar evolution and biological evolution. It is possible that no one recognized the importance of this phenomenon to date. Now we know: planetary evolution is a natural outgrowth of the logic of achievement; it is governed by the law of strata. What are the implications of this discovery?

First, the existing current scientific theories in several fields, such as elementary particle physics[17] and (Darwinian) evolutionary biology[6,8], acknowledge the importance of neither humanity’s place in the universe nor our existence on Earth. Weinberg[29] famously remarked that nothing that scientists had discovered suggested to him that human beings have any exceptionality with regard to the laws of physics or in the initial conditions of the universe. He[29] and Feynman[27] considered the universe as the present consequences of the initial conditions of the universe, the universal laws governing it, and accidental and historical events under the scope of sciences like biology, astronomy, and geology. Such a worldview is consistent with Darwin's evolutionary theory in that he explicitly rejected the notion of evolution constituting progress[8,25]. As successors of Darwin, Gould[25] and Mayr[8] agreed that our uniqueness arises from the operations of ordinary evolutionary processes, not from any predisposition towards 'higher' beings. Today, educated people accept the evolutionary continuity between humans and apes. However, the idea of the world as simply accidental is flawed, as demonstrated by the following question: Why was Einstein more intelligent than an ape? Such a question had also intrigued Feynman[16] in his lifetime. This question has led us to discover planetary evolution by natural law, which renders the complex world as we perceive it utterly non-accidental. Planetary evolution by natural law, which is not an anti-Darwinism theory, can restore our place and our existence to their fairly intuitive importance (Fig. 2a, b, and c). Humanity holds an important place in the universe and belongs to an important existence on Earth－the Western religious, anthropocentric tradition－which Darwinism had strongly challenged. Furthermore, the logic of achievement allows for a science-based natural ethics which Darwinism failed to create. We will return to this issue below.

Second, this new scientific discovery bears on all sciences[19]. We provide implications of our discovery for scientific progress in elementary particle physics, biological evolution, ecology, and neuroscience. In elementary particle physics, scientists seek those fundamental principles from which all other scientific principles can in principle be derived[29]. Although many in the field consider that a correct Grand Unified Theory will posit no special status for life and intelligence, the set of principles in this final version would be the only logically consistent set of principles that support the appearance of intelligent life in the universe. This is known as the anthropic principle[29,31,32]. However, current research into string theories[33] or other theories[31,32], which seek to provide a basis for a final theory, tend to make vague statements or prescribe values for constants of nature in a range that is more or less favourable to life[17,31,32]. We propose that elementary particle physicists may further validate their theories by making and testing mathematical predictions and deductions based on the law of strata. This step would also further bring confidence to the unification of scientific knowledge, given the extant knowledge gap between physics (and chemistry) and biology.

Planetary evolution extends our view of evolution to all planets. We can thus posit the question: Is Darwinian biological evolution by natural selection universal across all planets? The essence of Darwinism lays in its claim that natural selection creates organisms, of which some will better fit their environment than others[25]. Variation is ubiquitous and random in direction. The properties of DNA and related molecules allow organisms to pass on their genetic blueprint to their offspring[17]. Natural selection directs the course of evolutionary change. It preserves favourable variants and builds fitness gradually[25]. Darwinian biological evolution by natural selection thus appears to be a logical proposition: we deem it to be universal across all planets. However, since there are potentially many physiochemical paths to the origin of life, possible unseen mechanisms of heredity that could also drive biological evolution may be diverse. Nonetheless, this is a moot question. Molecular[34,35] and evolutionary biology[1-5] on Earth are in a state of flux. Recently, reports of newly detected exoplanets have been increasing weekly[36-38]. Studying the conditions for success for evolution into life which could appear in the biosphere of an exoplanet is an interesting predictive challenge[18]. Given the right conditions, humanity may soon be conducting research in the field of exobiology.

We now turn our attention back to ecosystems[39-41] and neural systems[42-45] on Earth. A serious practical limitation to understanding them is the difficulty of comprehensively explaining their workings[8]. However, it may still be true that very simple principles govern sciences of complexity, even given the immense complexity of the embodiments of the principles: e.g. ecosystems and neural systems (Fig. 2a, b, and c). We propose that the homo-ecosystem (Fig. 2c) may serve as a universal theory in ecology, thanks to its governance by a simple natural law and its status as a success/failure system with a three-level structure and related dependency relations. We are living in the Anthropocene epoch, the period of time in which humans certainly stand on the topmost level of the homo-ecosystem. Among our unique qualities, our propensities to kill each other and to destroy our environment jeopardize our existence[23]. The law of strata may guide ecologists to build general ecosystem models[46] (GEMs) based on deep knowledge of the unique workings of individual ecosystem acquired through observation and analysis. GEMs based on a universal theory are likely to be easier to communicate among ecologists than GEMs that are not, and could radically improve our understanding of the biosphere and inform policy decisions about biodiversity and conservation.

Similarly, we propose that neuroscientists may incorporate the two-level structure of animals and the three-level structure of humans (Fig. 2a, b) into their theoretical neuroscience to make sense of how the brain works. Most neuroscientists agree that the brain's complexity holds many mysteries yet undiscovered. Their quest for learning what all the firings of neurons mean in terms of animal and human behaviour shows no signs of slowing down[42-45]. We hope that our discovery will shed some light on this frontier of scientific research, which shows substantial support from bodies such as the NIH BRAIN Initiative and the European Commission's Human Brain Project.

Last but not least, this discovery about planetary evolution brings implications for today's global challenges of sustainability[47-50]. Perhaps its most remarkable point is that the biosphere of a planet constitutes the largest success/failure system on that planet, which follows the logic of achievement. The biosphere on Earth is a homo-ecosystem with a three-level structure and related dependency relations (Fig. 2c). We, humans, standing on the topmost level of the system, are custodians of the whole system: arrogance and hegemony towards the two lower layers, and towards each other, do not benefit this high position. It is commonly believed that the ecosystem is degrading, but in reality it is the whole system, the homo-ecosystem, that is. As the largest system in our planet, the homo-ecosystem is all-inclusive, and if there is one system that we must maintain and sustain, the homo-ecosystem is it. This is not an emotional plea, but a scientific conclusion.

Without this scientific understanding, today's global challenges of sustainability on Earth present confusion, paradoxes, lack of confidence, conflicts, and ambivalence which permeate the globe. Humans are in peril, but they are currently helpless to address it. Furthermore, since we need to maintain and sustain the biosphere, the biosphere's sustainability is logically speaking our ultimate concern. Thus, planetary evolution by natural law provides us with a scientific basis for a natural ethics[8]. There is no such science-based natural ethics today: modern science does not touch on value, and is in fact considered value-free[17,18]. It is true that Darwinism ousted religious ethics, but his theory could not account for humanity's moral responsibility to Earth[8]. Citizens, scientists, politicians, educators, and policy-makers alike acknowledging that we are *truly* facing global challenges of sustainability on Earth and that we are *morally* responsible for the outcomes are important first steps towards concerted action. We hope that our discovery about planetary evolution may also provide guidance towards appropriate actions, such as organized efforts at the United Nations. Humans may be led to the goal of sustaining Earth as an exemplar to which planetary evolution in the universe naturally tends.

8 Conclusions

The Big Bang set forth the visible universe: the universe in turn has existed for 10 to 15 billion years, and it will doubtless continue for billions of years to come, and perhaps forever[29]. The origin of the universe is perhaps the most interesting question that humanity can pose. The beginning of the 21th century has seen the discovery of the Higgs boson[10] and evidence of this aboriginal explosion[11] from BICEP2: these findings greatly advance our understanding of cosmological evolution, and inspire the human spirit[29]. On the other end, how the universe evolves from an explosion at its outset to create great entities like Earth, Einstein, and apes also interests us: man's main concern should be for mankind[18]. To this end, our work addresses the problem of planetary evolution.

In 1859, Darwin discovered biological evolution by natural selection, a process that seems to overlap non-intuitively with planetary evolution by natural law since both kinds of evolution can occur on our planet and concern both life and intelligence. We have discovered that planetary evolution is a consequence of the logic of achievement, and that it is governed by the law of strata. We have also provided some important implications for natural ethics, scientific progress, and the global challenges of sustainability on Earth, as well as our place in the universe. We anticipate that the law of strata will be found to form the background to all natural laws in the universe. More than three hundred years ago, in 1687, we knew that all planets move according to the law of gravitation. Now, in 2015, we also know that they evolve following the law of strata.

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