Section One
INERT MATTER

The Universal Grammar of Evolution

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The evolution (sensu lato) of the cosmos can be divided in three phases: cosmological evolution (sensu stricto), biological evolution and cultural evolution. Analogies between biological and cultural evolution date from the nineteenth century although it is only in the past two decades that so-called cultural evolution research has exploded. By contrast, comparisons between cosmological evolution and either biological or cultural evolution are uncommon. Here, we compare these three kinds of evolution and try to delineate their common grammar. Do their structure and underlying dynamics have characteristics in common? We believe that this is indeed the case and also that this Universal Grammar of Evolution can and should be used as a heuristic template in the study of these three kinds of evolution. Furthermore, this provisional template also might help scholars in their attempts to sketch the future course of a possible fourth kind of evolution, that of artificial intelligence and intelligent machines.

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Introduction

In the beginning, there was not the word, but pure energy. The cosmos as we know it today has, so to say, lifted itself out of this homogeneous and relatively simple energy soup, much like Baron Munchausen rescued himself and his horse out of a swamp by lifting himself up by his pigtail. Put differently: the solar system, Earth, life, man, the Eiffel tower or even the first World War, *The Origin of Species*, the Mona Lisa and the worldwide web were already potentially present in the primordial state of the universe. How did the dizzying complexity and heterogeneity of our world and the modern cosmos come into being in the course of the past 13.8 billion years? The short answer to that question is: through a long process that we know as cosmological (i.e., physical and chemical), biological and cultural evolution. Or, as Kurzweil (2005) puts it: through the epochs of physics and chemistry, biology and DNA, and brains and technology. Also, each epoch built upon the one before it: evidently, without cosmological evolution (*sensu stricto*), there would have been no biological evolution and without biological evolution no cultural evolution.[1]

In each one of these three distinct epochs, a relatively simple and homogeneous state was developed into a much more complex and heterogeneous state. In other words, order evolved at different scales, from particles to societies. It is this development that we here call 'evolution': not only energy and matter went through so-called phase changes (e.g., the emergence of the first particles out of matter) but also the evolution of the Universe. The term 'evolution' is derived from the Latin 'evolutionem' (the 'unrolling' of a book) (Bowler, 1975). One could therefore also say that the book of the Universe consists of three parts. We are here interested in the features that these three parts have in common, not in the features that are specific to one or two of these three kinds of evolution.

Cosmological, biological and cultural evolution indeed each have their own, distinct characteristics. For example, biological evolution is largely (but certainly not exclusively) adaptive but adaptation does at first sight not seem to be characteristic of cosmological evolution. However, we believe that these three kinds of evolution also have some features in common. It is these common, fundamental features that we here call the Universal Grammar of Evolution (henceforth UGE) (section 3). It encompasses a structure and a dynamic. First, however, we will briefly compare this UGE with other, similar universal grammars (section 1) and distinguish it from the idea of Universal Darwinism (henceforth UD) (section 2).

1. Universal grammars

Of course, we are not the first scholars to delineate a 'universal grammar' of something or to at least make an attempt at delineating such a grammar. For example, Thomas S. Kuhn's *The Structure of Scientific Revolutions* (1962) is inspired by the idea that the manifest heterogeneity and pluriformity of scientific revolutions hides a common structure. Therefore, his book might as well have been entitled *The Universal Grammar of Scientific Revolutions*. Scientific revolutions are initiated by a crisis, which is elicited by a persistent and serious deviation in the way that nature behaves, compared to the way it should behave, according

[1] Another intriguing question is to what extent the three kinds of evolution and/or the three realms (independently from their evolution) influence(d) each other. If we consider the developmental history of Earth as part of cosmological evolution, it definitely had a major impact on the evolution of life and on cultural evolution (see, e.g., Dietrich et al., 2006). Conversely, the evolution of life also had an impact on the evolution of Earth (see, e.g., Watson, 1999). In a similar vein, our biological and cultural evolution have always been very much correlated (bio-cultural evolution; see, e.g., Cochran & Harpending, 2009; Henrich, 2016).

to a particular, established theory or disciplinary matrix (i.e., a paradigm). If efforts to solve these anomalies with the help of the extant paradigm keep failing, a community of researchers can lose its confidence in that paradigm and become receptive to an alternative theoretical framework. If one of these alternative theories solves the anomalies and shows sufficient promise in guiding the research of the community, it will replace the extant paradigm and become the new paradigm (i.e., cause a scientific revolution).[2]

In a similar way, the science of networks studies what might be called the universal grammar or the structural architecture behind a wide array of complex phenomena like epidemics, brains, social networks or the internet. It thus observes and delineates "the architecture of complexity" (Barabási, 2003: 225): "amazingly simple and far-reaching natural laws govern the structure and evolution of all the complex networks that surround us" (p. 6). More specifically, so-called scale-free networks are made up of interconnected hubs that operate on the Power Law: a few hubs (websites, persons in social networks, super-spreaders in epidemics) are much more important than most other hubs.[3] Likewise, Rosemont and Smith (2008) speak of a "universal grammar of religion" (i.e., fourteen points of similarity among the major religious traditions which allegedly indicate an innate human affinity for religion), and Perfetti (2003) of a "universal grammar of reading" (i.e., a number of properties that can be seen across all reading systems). It is therefore maybe surprising that no one has, as yet, tried to delineate an UGE, at least not to the best of our knowledge.[4]

2. The comparison with Universal Darwinism

New or not, the idea of a UGE certainly resembles the idea of a UD (e.g., Dawkins, 1983; Christian, 2015; Campbell & Price, 2019). In many scientific fields, 'selection' is proposed and discussed as an important mechanism, underlying the evolution of a wide array of systems or phenomena: quantum physics (Zurek, 2009), anthropology and archaeology (Cavalli-Sforza & Feldman, 1981; Boyd & Richerson, 1985; Mesoudi, 2004), cosmology (Smolin, 1998), immunology (Müller et al., 2018), etc.[5] Apparently, natural forms of selection are in important ways antecedent to the order and complexity that is so paramount in our Universe. Smolin (2005: 34) even believes that it is the *only* way that complexity can increase against the tide of entropy. The entities that are selected are self-replicating organized information systems (i.e., systems, able to continuously decrease entropy locally).

[2] Of course, this model of scientific revolutions is not generally accepted. Nor do we have another generally accepted model of how scientific revolutions or major changes in the sphere of science take place (see also Leroi et al., 2020). As Nickles (2017) puts it: "Today there are entire academic industries devoted to various aspects of the topic of scientific revolutions, whether political or scientific, yet we have no adequate general theory or model of revolutions in either sphere."

[3] It should be added, though, that recent research (Broido & Clauset, 2019) has called the ubiquity of scale-free networks in question. Apparently, only about four percent of real networks can, strictly speaking, be called scale-free. Which leaves the question open as to what the common architecture or grammar of those networks is.

[4] (Grinnin & Grinnin, 2019), for example, certainly come close with their study of "similarities between evolutionary laws, principles, and mechanisms at various levels and phases of Big History" (p. 99).

[5] Descriptions of 'selection' vary (e.g., Smolin, 2005: 34; Blackmore, 1999: 10-11; Lewontin, 1970) but it requires (1) variation, (2) the elimination of certain entities and retention of others, and (3) a replication or reproduction of the selected or retained entities. Therefore, it can be characterised as an exponent of a more universal interplay between chance (variation) and necessity (elimination/retention and replication) (Monod, 1970).

Recently, Campbell and Price (2019) proposed a more complete and formal definition of UD. It is highly speculative but also opens new roads and sets exciting challenges, especially for cultural evolution. First, if Darwinian evolution is simply local entropy reduction, one can speculate that the evolution of cumulative culture is just a means, found by brains and cultures, to decrease entropy even further. That would imply that entropy and information theory could provide us with a comprehensive definition of cumulative culture (which is still debated), as well as with tools for measuring it. This would be particularly useful in anthropology and archaeology. Also, considering entropy as central to cultural evolution opens up an original interpretation of ethics: Vidal and Delahaye (2019) propose that simple moral rules could be based on the condemnation of entropy-increasing behaviour. Second, Campbell (2016) speculated that, under UD, evolving systems are all based on Bayesian inferential processes, which means that information is continuously updated and, through interactions with the environment, re-structured.[6]

However, even the most ambitious versions of the theory of UD are not quite the same as the UGE that we have in mind since 'evolution' encompasses much more than selection. For example, as we shall shortly see, constructive interactions and destructive events or processes form important components of the UGE. In fact, selection is not even a certain or necessary part of our tentative interpretation of that grammar. It is, after all, merely an explanans of biological adaptation, a phenomenon which is, as aforementioned, probably not inherent to the evolution of the cosmos.

3. The Universal Grammar of Evolution

Our delineation of the structural and dynamic properties ('grammar') that cosmological, biological, and cultural evolution have in common is very preliminary and provisional: it is merely a first attempt and an invitation for further research. Also, it should be pointed out that there is a speculative side to some of the parallels that we discern.

These parallels are the following. Firstly, the evolution of the cosmos, of life and of human culture(s) is, each in its own way, a manifestation or expression of information. Furthermore, each one of these three kinds of evolution starts out, or emerges from a state of primordial plurality: for sustained evolution to occur, circumstances have to be just right. Put differently: many entities (e.g., primitive lifeforms on other planets) remain stuck in a state of primordial simplicity and homogeneity (i.e., steady state non-evolution). Evolution starts in earnest after the occurrence of a seminal event (the first threshold). It is followed by a series of (further) structural thresholds. There also is a micro- and macro-dimension to evolution, as well as a horizontal and a vertical dimension. Lastly, different forms of cooperation or constructive inter-action ('self-organisation') play crucial roles in the dynamics behind evolution, next to (and sometimes entangled with) antagonistic interactions and forms of destruction. Furthermore, these dynamics are also characterised by an interplay between chance and necessity. The process that we call selection is but an example of this interplay. In what follows, these six structural and three or four dynamical components of the universal grammar of evolution will be briefly illustrated.

[6] Some scholars have pushed the implications and consequences of UD to the limit. Price (2019) and Vaas (2019), for example, proposed that the ultimate manifestation of our evolving universe would be the emergence of an intelligence, able to tame the cosmos by enhancing cosmological selection (*sensu* Smolin, 1998).

3.1. The universal structure of evolution

3.1.1. An expression of information.

Cultures are expressions of cultural information and organisms of biological and particularly of genetic information. In the 1990s, research on black holes inspired the idea that, likewise, universes might be manifestations of what could be called cosmological information. According to the counter-intuitive concept of the holographic Universe, our Universe, including time, emanates from a flat two-dimensional field at its boundaries. Through the work of the Argentinian physicist Juan Maldacena (1997), this idea has become an important heuristic theory (it has for example been used to explain cosmic inflation). It might one day even reconcile Einstein's theory of gravity and quantum theory. That final theory of everything will, in any case, probably not be concerned with fields or space-time but rather with information exchange between physical processes. However, for now, there is still no definite empirical proof that what we perceive as reality must be conceived as a 3D projection of a 2D field.[7]

3.1.2. A state of primordial plurality.

A second and also somewhat speculative feature of the universal structure of evolution is a state of primordial or primitive plurality. Smolin (1998: 44) points out that nature is not as simple as physicists often claim. A really simple universe would, for example, be a universe, filled with a homogeneous gas of neutrons with a constant temperature and density. Compared to such universes, ours is "extraordinarily complex and varied!" And he adds: "We must understand how it came to be that the parameters that govern the elementary particles and their interactions are tuned and balanced in such a way that a universe of such variety and complexity arises" (ibid.).

One possible explanation for this conundrum is that there are (or have been) a very large number of universes and that only ours had, by chance, the right parameters to evolve and eventually produce life (the weak anthropic principle). Certain physicists, like Andrei Linde, even believe that this (i.e., the concept of the multiverse) is the only rational explanation. However, it is only if there are (or have been) at least 10^{229} universes that it becomes probable that at least one of them will, by chance, evolve to contain a variety of stars and other complex structures. We will later come back to Smolin's alternative explanatory scenario (the parameters change through time but in such a way that the emergence of a complex and biophilic universe becomes increasingly more plausible). For now, it suffices to say that it is not impossible that the evolution of our complex Universe emerged from a state of primordial plurality (i.e., a state, characterised by the existence of many universes, of which most did not evolve or underwent only minimal evolution).

Such a state has almost certainly preceded the evolution of complex life on our planet. We still do not have firm proof, but life has almost certainly popped up in various places, both on Earth and elsewhere in our biophilic Universe. However, in most cases, it probably has not undergone a meaningful or extended evolutionary development.[8] Mars may very well

[7] This may change in the near future: new research by Achúcarro et al. (2019) shows how the idea of the holographic universe might be empirically tested.

[8] Complex, let alone (highly) intelligent life indeed is not necessarily ubiquitous. In most cases or places, life probably does not exist for a long time or does not attain a high degree of complexity (i.e., does not evolve much or even not at all), if it emerges at all. Maybe, only Earth has the right parameters for the evolution of complex and intelligent life. Put differently, it is very well possible that man is the only highly intelligent and technological species in the universe. See Tegmark (2017: 241-245), Gribbin (2011) and Davies (2010). See also note 17.

have been such a biophilic place. It had liquid water and was probably habitable for primitive lifeforms during the so-called ancient Noachian time period (4,1 to 3,7 billion years ago).[9] The study of Mars rock and soil samples has revealed the existence of key chemical ingredients for life, including sulphur, nitrogen, hydrogen, oxygen and phosphorus, and we also know that this planet once had a magnetic shield. NASA astrogeologist and expert on Mars Christopher McKay (1997: 269), for example, believes that "if life arose on Earth, then it could have arisen on Mars as well."

In the case of cultural evolution, the state of primordial plurality is very evident: a crucial distinction in the cultural evolution literature is that between cultures in general and the specific phenomenon of cumulative cultural evolution (henceforth CCE) (Mesoudi & Thornton, 2018). Many researchers believe CCE to be unique to human beings. Indeed, this is how this concept was first brought to prominence by Boyd and Richerson (1996) and Tomasello (1999): to contrast human cultures with non-human cultures. However, there is no agreement about the exact definition of CCE. Mesoudi and Thornton (2018: 2) refer in this respect to four core criteria: a change in behaviour or a product of behaviour, a transfer via social learning of that modified behaviour or product, an improvement in performance, in terms of genetic and/or cultural fitness, caused by this behaviour, and a repetition of these three steps "in a manner that generates sequential improvement over time" (p. 2).[10] Whether one calls it CCE or not, and however one chooses to define it, it seems to us to be an undeniable fact that many biological species have a form of culture and also that forms of improvement of those cultures, or of elements of those cultures, sometimes occur but that *meaningful or extended* cultural evolution has been produced or generated by only one taxon: the genus *Homo*.

3.1.3. A seminal event (the first threshold).

What was the seminal event that started up the process of CCE? Henrich (2016) believes that by 1,8 million years ago, the threshold or Rubicon of cultural evolution had already been crossed but he does not offer a definite answer as to how it was crossed and why this only happened once in the history of life on planet Earth. He speaks in this respect of the start-up problem. CCE depends on social, as opposed to individual learning and requires a big, costly brain. Also, in order for natural selection to favour improved social learning, a lot of cultural information must already exist, which is a problem because, without pre-existing social learning capacities, it is unlikely that there will be much cultural information to tap into. Henrich's speculative solution for this classic chicken and egg problem does not interest us here. The main point is that it was the development of advanced social learning that facilitated the birth of cultural evolution and that both were interconnected: CCE stimulated the development of social learning and vice versa.

A somewhat similar chicken and egg problem exists in the case of biological evolution. As Christian (2018: 97) puts it: evolution "really got going" only after the development of a DNA world by the descendants of LUCA, the 'last universal common ancestor.' This is when the most important distinction in life as we know it, that between nucleic acids, which carry information and proteins, which generate the phenotype, came into being. This is also the opinion of Maynard Smith and Szathmáry (1995: 12): "Perhaps the most important transition of all is that between organisms in which both the genetic material and enzymes were made of RNA (the RNA world) and modern organisms in which the genetic material is DNA and

[9] The oldest known fossils are also 3,7 billion years old (Nutman et al., 2016).

[10] CCE can also be interpreted as a means, 'found' by the universe, to decrease entropy even further since it can decrease the degree of uncertainty of a group of humans in a given context.

enzymes are proteins – a division of labour that requires that there be coding and translation." In modern organisms, nucleic acids and proteins mutually presume one another and it seems, as the authors point out, that "neither can function without the other" (p. 61). Hence the chicken and egg problem: "Which came first, nucleic acids or proteins?" (ibid). It is still unclear whether both co-evolved or whether one of both came first. The main thing, however, is that the seminal event in biological evolution was the emergence of DNA/protein lifeforms.

According to modern estimates, the last phases of the Universe will probably be characterised by extreme and increasingly extended timescales (trillions upon trillions of years), to the point that time itself will become meaningless. The beginning of the Universe is characterised by exactly the opposite phenomenon: unimaginably tiny timescales. For instance, the Planck epoch (i.e., when the Universe was smaller than the "Planck length") lasted about 10^{-43} seconds, whereas the inflationary epoch, which started approximately 10^{-10} *second later, lasted approximately* 10^{-20} seconds. During this tiny fraction of a second, the volume of the Universe expanded with a factor of 10^{78}. It was not the start of the evolution of the cosmos, in the same way, that Henrich's Rubicon was not the start of cultural evolution or the advent of the DNA world the start of biological evolution, but it is definitely only after this first threshold that cosmological evolution "really got going." Without inflation, stars, galaxies or other complex structures wouldn't exist, as it were quantum fluctuations in space-time that caused different parts of the Universe to stop inflating at slightly different times.[11] This was important since it was the resulting variation in the density of matter in those different parts of space that allowed gravity to condense pockets of gas into stars. One might also say or suggest that the inflated Universe thus functioned, in a way, as the equivalent of Earth (for biological evolution) and man (for cultural evolution): it facilitated its own evolution.[12]

3.1.4. Structural thresholds.

The further evolution of the cosmos, life and human culture was characterised by the occurrence of new, small and big thresholds, such as the formation of the first atoms, stars, planets and heavy elements (cosmological evolution), the coming into being of the eukaryote cell or multicellularity (biological evolution, see, e.g., Maynard Smith & Szathmáry (1995)) and the taming of fire, the Neolithic revolution, the invention of the wheel and the emergence of the first cities and states (cultural evolution).[13] To use the aforementioned book metaphor: each 'part' (i.e., each kind of evolution) of the cosmological 'book' consists of several chapters.

3.1.5. Two binary dimensions.

Lastly, evolution, be it of the cosmological, the biological or the cultural kind has, from a synchronic perspective, a micro- and a macro-dimension, as well as a horizontal and a vertical

[11] According to the theory of eternal inflation, many different patches of the cosmos can start inflating and blow up to new universes. Koonin (2007) uses this concept or theory to account for the (improbable) origin of life on Earth: in such a multiverse, the coming into being of a complex, coupled system of translation and replication through chance is possible.

[12] As pointed out before (footnote 3), Earth co-evolved with life and man with his cultures but it probably does not make sense to say that the inflated universe co-evolved with the (further) expanding universe (i.e., with itself).

[13] Maybe, a distinction can be made between thresholds that increase the evolvability (i.e., capacity to evolve) of a kind of evolution and thresholds that do not have this effect. For example, the invention of fire facilitated further cultural evolution and the emergence of multicellularity was a catalyst for further biological evolution.

dimension. As to the former dichotomy: cosmological evolution ranges from the evolution of the entire Universe to the evolution of a star system or a single planet, biological evolution from the evolution of the entire biosphere to the evolution of demes and cultural evolution from the evolution of civilisations to the evolution of cities or institutions. Horizontal evolution consists of the splitting up of evolving entities in two or more subentities, vertical evolution refers to a quantitative or qualitative change in one and the same entity (e.g., galaxy, species, or city). Evidently, cladogenesis or speciation is a very important process in the evolution of life: the bewildering heterogeneity of life as we know it today is largely a product of this process. Cultures too, can split up in two or more subcultures. Lastly, there is evidence that galaxies can also fall apart in two or more parts: after running simulations, involving the Large Magellanic Cloud, one of the satellite galaxies of the Milky Way, Bustard et al. (2019) recently discovered that the intense heat, produced by bursts of cosmic rays, can tear galaxies apart.

3.2. The universal dynamics behind evolution

The factors, forces and mechanisms that drive cosmological, biological and cultural evolution are very diverse. Are some of them common to each kind of evolution? Put differently: are there universal evolutionary factors, forces and/or mechanisms? We believe that the answer is affirmative. The real question is how many universal evolutionary factors there are.

3.2.1. Selection?

Selection processes explain biological and cultural phenomena. But do they also play a role in cosmological evolution? Smolin (1998) certainly believes that selection plays an important role in the (speculative) multiverse (but *not* in a single universe). According to his fecund universes thesis, a collapse of a black hole leads to the creation of a new universe (reproduction) that slightly differs from its mother universe (variation). Consequently, each Universe produces as many new universes as it has black holes. Universes with infecund parameters never 'reproduce' (for instance because they soon reach heat death or maximum entropy) or 'reproduce' less than universes with fecund parameters. This way, universes become increasingly fecund and the emergence of a biophilic universe becomes increasingly likely, particularly because carbon, which is central to life, is produced by black hole-generating supernova's. Unfortunately, it is thought that no information about a parent universe can survive the violent singularity at the centre (as opposed to the event horizon) of a black hole.[14] In any case, if we understand under 'cosmological evolution' the evolution of the multiverse, selection might be an important force behind it, although it should immediately be added that Smolin's interpretation of this process does not seem to be very plausible.

3.2.2. Constructive versus antagonistic interactions.

If there is a universal evolutionary force or factor, it is probably constructive interaction ('self-organisation'): this seems to be a conditio sine qua non for attaining higher orders of complexity. Evolutionary entities combine into entities of a higher order or swap parts, or one entity becomes part of another one (symbiosis): subatomic particles combine into atoms, atoms into molecules, molecules into tissues, cells into more complex cells (symbiosis) and into multicellular organisms, single organisms into groups and entire societies and galaxies merge or are swallowed up by bigger entities. Also, many organisms have sex, hybridise or

[14] See: 'Smolin Vs. Susskind: The Anthropic Principle' (2004). Available online: https://www.edge.org/conver-sation/lee_smolin-leonard_susskind-smolin-vs-susskind-the-anthropic-principle.

swap genes. This, in turn, maybe lends some credence to Margulis' (1998) claim that the standard theory of biological evolution (i.e., the Modern Evolutionary Synthesis), seriously underestimates the evolutionary importance of symbiotic and cooperative biological interactions and overestimates the role of competition.

However, as highlighted by authors like Dawkins (1976) and Maynard Smith and Szathmáry (1995), any biological jump in complexity, thanks to cooperation or constructive interactions, had its drawbacks with the appearance of new sources of conflicts and competition, especially between different levels of organization. For instance, the emergence of multicellular organisms was accompanied by intra-organism conflicts (such as cancer). Consequently, the emergence of more complex structures was often followed by the evolution of conflict-policing mechanisms (such as mechanisms to suppress the angiogenesis, invasion, and metastasis of cancers) and, thus, new layers of complexity.

3.2.3. Chance versus necessity.

Furthermore, cosmological, biological and cultural evolution are also caused by an interplay between chance and necessity and between negative (destructive) and positive forces or events. The question as to the importance of chance and human agency, compared to more structural and predictable, impersonal forces in human history, is a classic one. In biology, chance plays, for example, an important role in the generation of genetic variation and in genetic drift. Lastly, we already referred to the role that random quantum fluctuations in space-time played in the otherwise quite deterministic emergence of complexity in our Universe (they caused different parts of the Universe to stop inflating at slightly different times and thus caused the young, inflated Universe to be 'lumped').

3.2.4. Creation versus destruction.

Constructive interaction may be the main motor behind evolution, destructive forces and events certainly also play important roles in the emergence of higher complexity and more heterogeneity. This too makes perfect sense: the emergence of new, more complex entities often requires the destruction or death of more primitive entities. In the Universe, most galaxies have a destructive super-massive black hole at their centre. It is thought that this is no coincidence as they played an important role in their genesis: the jets of high-energy particles and radiation that active or 'feeding' black holes eject are believed to have triggered the birth of successive generations of stars and, thus, galaxies. Higher or heavier elements are formed in stars and ejected when they explode at the end of their lifetime. Everything that is composed of heavy matter, including the Earth and its living organisms, thanks its existence to these violent supernova's.

Another violent event, a catastrophic collision of young Earth and the Mars-size planet Theia, around 4.5 billion years ago, facilitated the evolution of life as we know it.[15] At that

[15] This collision is one of the reasons why Earth became, and still is, the ideal cradle for the long-term evolution of life, without either too much stability or too many disturbances. For example, the liquid-iron core of Theia joined up with the Earth's own liquid-iron core and reinforced its magnetic field, which acts as a shield against harmful solar and cosmic particle radiation. Also, so much of the Earth's surface was thrown into space (to form the Moon, which not only is the main cause of the tides, but also stabilizes the gravitational pull of the sun and Jupiter and thus acts as vital climate regulator) that only 30 percent of the original crust was left, which in turn al-lowed the continental plates to move around more easily. This continental drift became a key driver behind evolution. Lastly, the collision knocked Earth so that it was no longer spinning on a straight axis with respect to the Sun. This angle of tilt is the cause of the seasons, another important driver behind the evolution of life.

time, the evolution of life on Earth had probably not yet begun, but it would never have reached its current complexity without later, smaller catastrophes, including the impact of a meteorite in Yucatán (under a very specific and lethal angle of 60 degrees), 65 million years ago. Lastly, destructive forces and events also play central roles in cultural evolution: new, more complex civilisations are or were often built on the ruins of older, more primitive civilisations and new ideas, theories and technologies constantly replace older, abolished ideas, theories and technologies (i.e., Werner Sombart's and Joseph's Schumpeter's notion of 'creative destruction').[16]

Concluding remarks

Mesoudi (2015) enumerates a number of advantages, for the study of cultural evolution, of viewing cultural change as a Darwinian process. Conversely, evolutionary biologists can also benefit from the comparison with cultural evolution. As emphasized above, the here presented version of it is provisional and preliminary (and undoubtedly rudimentary), but we strongly believe that a UGE may, in a similar vein, be of use in the study of the three main sorts of evolution and maybe even in the study of a possibly emerging fourth kind of evolution, that of artificial intelligence or intelligent machines.

Intriguingly, it lends tentative support to both the idea of the holographic Universe and the idea of the multiverse. If both the biological and the cultural sphere can be interpreted as an expression of information, the same may be true for the cosmological sphere (i.e., the visible Universe may indeed be a holographic projection of a 2D 'source code'). Likewise, the fact that a state of primordial plurality was characteristic for both biological and cultural evolution makes it maybe more plausible that the idea of the multiverse is correct: the start of the evolution of our complex Universe may have been preceded by, or have coincided with, the existence and/or coming into being of a multitude of other, primitive universes. The UGE also suggests that a form of selection plays a role in the evolution of that, as yet, speculative multiverse (but probably not cosmological natural selection *sensu* Smolin).

Our UGE may also shed some light on an important discussion in biology. The aforementioned Modern Evolutionary Synthesis still guides a lot of research. However, it has always been controversial and has, in recent years, come under increasing attack from a number of scholars and biologists who investigate evolution under the guidance of the so-called Extended Evolutionary Synthesis (see, e.g., Laland et al., 2014, 2015). One of the main criticisms of proponents of this theory is that the Modern Evolutionary Synthesis interprets evolution almost exclusively in terms of adaptive processes, caused by the natural selection of genes. As we saw, selection is not even a certain part or component of our UGE. By contrast, constructive interactions and self-organisation are very much a part of it, something which chimes well with some of the alternative interpretations of evolution. Maybe an UGE can one day be an important source of inspiration for a long-sought-after, new or updated and more comprehensive evolutionary paradigm.

Lastly, there is also the idea of a fourth kind of evolution, that of intelligent machines. It has in recent years become more popular or mainstream, but was first formulated in the late nineteenth century, in the wake of the breakthrough of the idea of biological evolution. In his *Erewhon: or, Over the Range* (1872), Samuel Butler introduces the Victorian reader to a world that was strangely familiar but at the same time also very unfamiliar. It counted a royal

[16] However, complexity can only increase through destructive events if the destruction is not complete: there must remain some partial information or structure intact. For example, complex atoms after the explosion of stars and laws, tools, buildings or writings after the fall of civilizations.

court, judges, lawyers, banks and universities but was on the other hand also characterised by strange habits, beliefs and convictions. For example, Erewhonians did not believe in an afterlife but in a before-life, illness was conceived as a crime and crime as an illness, births were seen as tragic events, and so forth. The protagonist also relates how Erewhon banned, at a certain point in time, machines: only rudimentary tools were allowed. This was done on the advice of a visionary scientist who foresaw a future when intelligent machines would take over power in Erewhon. This kind of reversion to a more primitive state is also portrayed in Tegmark's *Life 3.0* (2017): it is one of the ways in which we could escape the perils of technology and, more particularly, superhuman artificial intelligence.

Will cultural evolution really culminate in this fourth kind of evolution? In the same way, that cosmological evolution produced biological evolution and biological evolution cultural evolution? One day, the current emergence of various forms of artificial intelligence and of intelligent machines may be identified as a state of primordial or primitive plurality. Some, and particularly Kurzweil (2005), also foresee a 'seminal event': the technological singularity, a point in time when an intelligent artificial agent enters a runaway reaction of self-improvement, resulting in an intelligence explosion and in the coming into being of superhuman intelligence.[17] It remains to be seen whether this, or a similar seminal event, will ever take place, but our UGE might very well help in assessing the probability of an emerging fourth kind of evolution and in predicting its possible course.

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[17] He sees the singularity as the fourth epoch and believes that it will lead to the fifth epoch: the awakening of the universe. Our template rather suggests that the singularity is the real start of the fourth epoch.

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