On the Epistemics of Metaverses

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Abstract
A metaverse may be defined as a network of computer-simulated virtual worlds focused on social connection. As the technology of creating and using metaverses matures, it is likely that scientific researchers may realize that some kinds of work can be done more efficiently in a well-constructed metaverse than in the irregular and expensive conventional world. To support that vision this paper uses Digital Reality theory to explore how metaverse computation may revise some of the basic concepts of human knowledge for its users. In effect, it asks *how can a reality generated by computers modify global ideas that form the foundations of scientific understanding?* Such a philosophical inquiry goes beyond ordinary database theory; it assumes that metaverses may become creative partners with humans in the scientific search for truth. Its findings suggest new disciplines for conducting research in a metaverse and include new computer-specific approaches to the concepts of knowledge, objectivity, time, and space.

Key words
Metaverse, knowledge, digitization, organic evolution, Digital Reality theory.

1. Introduction

This paper borrows concepts from an extended project to explore the effects of computer data processing on scientific epistemology, which has come to be called Digital Reality (DR) theory (Towner, 2018). During the last forty years this project has mined technological advances in the personal computer industry to find areas where scientific theorizing might be made more compatible with human epistemology. Three main areas of useful change have been identified: 1) recognizing that we humans routinely convert analog measurements to digital data; 2) supporting digital data by incorporating set-theory methods into scientific interpretations; and 3) allowing for the influence of organic evolution on the foundations of scientific research.

An important recent development in computer technology has been the concept of the *metaverse,* which Wikipedia defines as “a network of computer-simulated virtual worlds focused on social connection.” This arrangement suggests the possibility of conducting scientific research using human/computer “partnerships” where the foundations of such research would be programmed into metaverses, not based entirely on human understandings. The investigation presented here tries to foresee some of the areas of knowledge that such research might yield.

2. Historical perspective

The founding ideas of the modern scientific method were laid down in the 1830s and 40s by the works of John Herschel, William Whewell, and others (Whewell, 1840). However, several epistemological advances occurred after this effort, each of which has potential impact on the ways scientific research is conducted. Three major advances were:

2.1. *The development of digitization as a means for converting facts into data.* Advanced methods of digitization were unknown until the 1950s. Today, new algorithms for digitizing data are being constantly developed and put to work. Computers are used to solve scientific problems but the effects of digitization on defining those problems are not always taken into account.

2.2. *The concept of sets as valid epistemic objects with their own properties*. This was recognized for certain mathematical sets by Georg Cantor in the nineteenth century (Cantor, 1874); a workable axiomatic theory of sets of all types followed in the 1920s (Crosilla and Schuster, 2005). Set theory is logically prior to mathematics in the sense that sets can define the foundations of mathematics but not vice-versa. Yet the mathematical analysis of analog data remains a primary tool of science, as it has been since the seventeenth century.

2.3. *The insight that human knowledge is a product of organic evolution*. Darwin's work (Darwin, 1859) was eventually recognized as new knowledge. It explained the diversity of life on Earth by life's evolution instead of by its specific creation. However, organic evolution has not yet been recognized as the source of certain foundational concepts of science.

These three potential areas for updating the foundations of scientific research are discussed here in reverse temporal order. From the surface phenomena exposed by computer digitization, to the underlying problems explainable by set theory, to the ultimate effects of evolution on the models of physics, the most basic levels of science have been neglected philosophically. In effect, DR theory tries to suggest a response to physicist Lee Smolin's plea made to the current generation of physicists (Smolin, 2007):

> To continue the progress of science, we have to again confront deep questions about space and time, quantum theory, and cosmology. We again need the kinds of people who can invent new solutions to long-standing foundational problems.

The study that led to DR theory used the computer revolution to help illuminate the foundational problems that Smolin cites. We inverted the popular meme "people think like computers" and asked instead what computer architects were doing to make their machines think like people.

At every juncture during the history of computer technology, designers experimented with various ways to make computers smarter and more lifelike. An analysis of the resulting techniques (as well as of the techniques that didn't work) provided clues to support the epistemic findings of DR theory. Notice that this approach to knowledge—understanding phenomena by trying to reproduce them—honors some of the historic successes of laboratory science. From Boyle's and Hooke's deducing gas laws by building a successful air pump to the modern understanding of nuclear reactions that flowed from the Manhattan project, practical technology has often informed scientific advances.

3. What is digitization?

Hardware digitizers convert otherwise undefined mechanical variations into discrete step-like variations, usually of a different mechanical kind. For a simple example, consider an elevator indicator. The cab travels the entire height of the building, but knowledge of its position is useful only when it is at a discrete floor. So modern indicators use changing lights or numeric displays to convey digital floor information to the user. Note that early elevators, built before digitization was a recognized technology, rendered the position of the cab as an analog—the position of a pointer on a dial. The human user executed an analog-to-digital (A-to-D) conversion algorithm mentally by "reading the dial."

In DR theory, digitization is any process by which analog measurements are converted to digital data. For some physical properties the conversion is simple and standardized: temperature to degrees, movement to distance per time, pressure to force per area, and so on. In other cases, digitization can be done several ways. For example, there are at least three different ways to encode a graphic image digitally: by creating a bitmap, by specifying vectors, or by defining a geometric rendering. Bitmapping simply records a digital measure of the image's color at each point of a grid; this is also the way human and most animal eyes work. Vector graphics uses various techniques to draw the analog image. It has the advantage of being easily able to vary the image's size without distorting it. Computer rendering traces light paths through a virtual image plane, producing realistic results in both two and three dimensions at the cost of significant processing complexity.

To render complete visual experiences, machines often partner with the human brain. An example was cathode-ray tube (CRT) television before flat panel displays were introduced in the 1980s. In a CRT, the picture is painted by a moving dot of light—one dot for black-and-white, three dots for color. The dot, its intensity varying in response to an analog signal, zips back and forth like a tractor plowing a field. It draws a complete bitmapped picture thirty times each second, and successive pictures convey motion by their frame-to-frame differences. At any instant, the CRT exhibits only a dot of light of smoothly varying intensity. Yet what viewers saw and understood was not a dimming and brightening dot roaming back and forth. They saw the digital objects that the TV cameras had captured: people, things, discrete events. By performing natural analog-to-digital conversions, we humans understood an analog dot of light by constructing discrete experiences of visual objects and events in our minds.

From this and other examples, we conclude that humans are natural converters of analog data to digital data. We are forced to digitize our input data, because we process it digitally while living in a world that we access through analog means. Moreover, this requirement is not peculiar to humans; it appears to be a general characteristic of life. We find evidence for that conclusion in the "all or none law," first described by Henry Pickering Bowditch in 1871 and later confirmed by Keith Lucas (Lucas, 1909). The law states that responses to the stimulation of a living nerve or muscle fiber are uniformly either zero or maximum regardless of the varying strength of the stimulus. In other words, analog stimuli typically evoke digital responses. We and other living things use a basic digitizing algorithm on data inputs of all kinds: if the stimulus is above a threshold value the response is full ("1") and if it is below the threshold there is no response at all ("0"). Although it has been studied mainly in human tissues, the all or none law appears to be true throughout the animal kingdom (Lucas studied it in amphibians) and it probably holds for life in general.

Why do living organisms process data digitally, despite gathering it in analog form? We surmise it is because life is based on making successful decisions. In programming terms, it is the conditional branch instruction that contributes the most to making digital computers lifelike. We may expect that the computers in a metaverse will be deliberately programmed to emulate the ways in which humans understand the world. We bring analogs of external events into our sense organs—light patterns into our eyes, air pressures into our ears, motions onto our fingers—and those organs send electrochemical signals into our nervous systems. At some stage these signals (no longer the external events in their original states but analogs of them) are converted to clusters of organic yes-or-no bits, each of which conforms to the biological all-or-none law. To emulate sense organs, computer engineers have created electronic peripheral devices—microphones, cameras, electrical signal converters—all of which digitize the data they capture. In this way, computers try to "know the world" in the same ways that people do.

Historically, modern science has gained much of its credence by relating analog measurements mathematically. Galileo, who declared that the *filosofia* of the Universe was *scritto in lingua matematica* (Galileo, 1623), was echoed by Newton and Maxwell, who showed how the numerical analysis of existing analog measurements could yield predictions of future measurements. When Newton claimed in 1687 that his "mathematical principles of natural philosophy" had the status of laws, few objected. He and Leibniz developed methods of calculus to help digitize continuous change in analog data that appeared to obey those laws. As Newton's predictions of future events became more and more accurate, the logical strictness of mathematics seemed to contribute a bedrock of truth. In the modern era physicist Paul Dirac, who had succeeded to Newton's chair at Cambridge, wrote (Dirac, 1963):

> Our feeble attempts at mathematics enable us to understand a bit of the universe, and as we proceed to develop higher and higher mathematics we can hope to understand the universe better.

Most programmers will testify that understanding how a digital computer works requires only college-level mathematics enhanced by Boolean algebra. A computer programmed to execute Dirac's higher mathematics will normally use the same instruction set (add, multiply, branch, etc.) as any other computer; the complications lie in the meanings of symbols and how they work together, not in the operations required to manipulate them. At the level of discourse of most computer engineers, the difference between mathematical laws and digital explanations has been neatly described by computer scientist John Sowa (Sowa, 2000):

> In modern physics, the fundamental laws of nature are expressed in continuous systems of partial differential equations. Yet the words and concepts that people use in talking and reasoning about cause and effect are expressed in discrete terms that have no direct relationship to the theories of physics. As a result, there is a sharp break between the way that physicists characterize the world and the way that people usually talk about it.

Every item of knowledge that a digital computer handles is encoded as a set—normally, either a set of bits or a set of 8-bit bytes. Thus, to understand the ways that metaverse computers might support human science we must first understand how knowledge can be stored in sets.

4. The role of set theory

The numerical analysis of analog data goes back more than two millennia to the works of Euclid, Pythagoras, and Archimedes. Disciplined analysis of digital data in terms of sets commenced with a single paper published by Georg Cantor in 1874. Cantor's revolutionary idea was that sets could be new mathematical objects distinct from their elements and therefore deserving their own formal theory. Cantor at first defined sets as groupings of distinct objects of our intuition or our thoughts [in the original, "*Wohlunterschiedenen Objekten unserer Anschauung oder unseres Denkens*"] (Cantor, 1874). Particularly when it manipulated infinite sets, Cantor's new theory provided tools for formalizing thought, not for describing external reality. As set theory gained wider acceptance the concept of a set became more objective. In Felix Hausdorff's seminal guide book, *Grundzüge der Mengenlehre*, a set is defined as "a gathering of things into a whole, *i.e.* into a new thing" ["*Eine Zusammenfassung von Dingen zu einem Ganzen, d.h. zu einem neuen Ding*"] (Hausdorff, 1914).

The concept of a set as a new thing, instead of just a grouping of ideas, helped pave the way for set theory to be incorporated into twentieth-century quantum mechanics and information theory. Just as mathematical measurements such as energy and mass had become objectified as the independent properties of things, so sets such as tensors, transformation groups, and quantum states now became objectified as concrete things to be studied and known independently of their members—in effect, to become new objects of scientific study.

By the 1920s several axiomatic systems had been proposed to formalize set theory, of which that of Zermelo and Fraenkel ("ZF") is today the most commonly used. The ZF axioms were devised to provide mathematicians with ground rules for formulating paradox-free statements that could be proven logically within a universe of sets (Tiles, 1989). Two of them are of particular interest for the present discussion: the ZF null set axiom and the ZF powerset axiom:

4.1. The null set axiom declares: *There is an empty set, one that contains no elements.* This is the only ZF axiom that defines a specific set. Because the null set is empty it is unique; there is only one such thing in a given universe of sets. It is written $\{\}$. Every other set is constructed by using other ZF axioms to add elements to $\{\}$. This resolves the question of whether or not a given set is an independently existent object; just remove its elements and you end up with $\{\}$, which is unique and has been declared axiomatically to exist.

4.2. The powerset axiom guarantees: *For every set there can be a set whose elements are all its subsets.* This ZF axiom establishes a potent way to construct a new set (called a *powerset*) from a given set (its *base set*). For example, if a set contains three elements—x, y, and z— its powerset contains eight elements, all of which are sets. In set notation, the powerset of the set $\{x, y, z\}$ is written

$$\{\{\}, \{x\}, \{y\}, \{z\}, \{x, y\}, \{x, z\}, \{y, z\}, \{x, y, z\}\}.$$

This powerset contains every set that can be made using the elements x, y, and z, including a set that contains none of the elements (the null set) and the original base set, which contains all of them.

DR theory imports axiomatic set theory to provide its logical framework. When applied to metaverses it also assumes that human knowledge can be expressed entirely in sets. This assumption will hold as long as the knowledge in metaverses is processed using current computer technology, because mainline software can always be written to handle sets of bits. Moreover, sets can represent either objects of knowledge—by listing an object's parts and attributes—or categories of objects, by listing object sets that participate in a given category. It also appears that axiomatic set theory can define mathematical operations but not vice versa.

An axiomatic set theory such as ZF provides logical tools for manipulating sets—nesting them, combining, comparing, etc.—without spawning paradoxes. In fact, it should support the aggregation of all scientific knowledge into one body of nested sets and their categories. But after Descartes argued successfully for mind-body duality in the seventeenth century it has been extremely difficult to propose a single epistemic tree that would durably embrace the phenomena of physics, the subjective experiences of psychology, and the truths of mathematics.

5. Foundational types

Analyzing the Cartesian mind-body problem as a problem in set construction, not a problem in epistemology or ontology, DR theory finds the sort of solution that a programmer might adopt. It identifies three very large sets that could represent *foundational types* in scientific theorizing—categories that belonged to no higher categories. It names them "behavior," "physical reality," and "ideals."

These foundational sets are well known in classical philosophy, if not in strict science. *Behavior* is the Cartesian "mind," updated by modern neurology. It is the set of all our internal experiences, urges, and undertakings. Its set members include *qualia*, of which philosopher C. I. Lewis wrote, "The quale is directly intuited, given, and is not the subject of any possible error because it is purely subjective" (Lewis, 1929). *Physical reality* is the subject of hard science, roughly corresponding to classical philosophy's concept of "substance." The set that DR theory calls *ideals* corresponds to the same school of thought's concepts of "forms" or "universals," and includes entities defined by the abstract sciences such as mathematics and symbolic logic.

Conceptually, the three types of sets just described—behavior, physical reality, and ideals—are all objects of knowledge. Yet they strongly resist being united as subsets in any other single set. It may even be regarded as a mental defect if a person cannot discriminate between the experience of seeing red, the red peel of an apple, and the frequency range of red light. Nevertheless, these sets can be linked through the ZF powerset axiom. DR theory suggests a simple formula: *physical sets are powersets of behavioral sets and ideal sets are powersets of physical sets* (Towner, 2020). A base set's powerset tells us all the ways that new sets could be constructed using any subset of the base set's elements. This display of new possibilities for using existing set elements, we suggest, is evolution's way of proceeding forward. It lets existence be *understood* in a way that inorganic events can never achieve: from inner experiences to models of an external world and from there to generalities. It helps answer the question: *how does knowledge work?*

Note that this progression—from behavioral to physical to ideal—cannot easily be expressed by the mathematical analysis of analog data; it requires digitization and set theory to make sense. Here are minimal details of one possible implementation in ZF set theory, using Cantor's original criterion of one-to-one mapping to understand why the DR theory's foundational sets are not comparable:

5.1. At the entry level of knowledge, living things sense and react digitally to external stimuli, a process called behavior. Experiences are stored in a behavioral world distributed among organisms: their totality can be described logically as a set of countable sets, each linearly ordered by time.

5.2. At the operational level of knowledge, all the possible ways that behavioral elements can be embodied physically comprise the physical universe, which is an uncountable set. This is the common world, ordered in time and space, that science studies and calls reality. The uncountability of its elements and the multiple dimensions of their spatial distribution distinguishes it in a fundamental way from the totality of behavior.

5.3. In the abstract level of knowledge, physical sets are aggregated into a set of generalizations sometimes called a “functional manifold.” One can visualize it as the set of all the ways we can combine and relate physical sets. This is the world of abstractions, universals, and essences, all based on generalizing both behavior and physical reality. Science uses parts of it—mathematics, geometry, topology, and other logical disciplines, including axiomatic set theory—to express theories about the rest of knowledge.

Besides establishing sets as real things, Cantor assigned to every set a *cardinality* that designated the number of its elements. This allows set theory to serve as a foundation for numerical analysis. It also helps integrate the practical use of sets in mathematics. Early in the twentieth century Richard Dedekind used methods of dividing set elements to improve our understanding of the structures within countable, uncountable, and manifold sets. In metaverse software, these “Dedekind cuts” can help determine a programmer’s usage of digital storage types. For example, stacks and arrays are appropriate to hold digitized linear behavior, heaps and file structures to hold random-access physical information, and relational databases to hold linked ideals.

To summarize, sets isolate themselves from other sets because they are entities distinct from their elements, but at the same time they link information by sharing elements. This dual functionality is clear in digital computers because they process sets that ultimately contain only bits. Computers repurpose these identical elements in multiple ways to form representations of everything that can be known in a metaverse.

6. Time and space

The concepts of time and space are deeply rooted in the foundations of science, but they have long puzzled philosophers. Newton thought they were innate properties of nature, Kant called them human “intuitions,” and Einstein anchored them to the propagation of light. In computer technology they almost disappear. Computers have clocks, but their purpose is to enforce program steps—in effect, to define “before” and “after.” Whether a digital computer executes a million program steps a second or one a day makes no difference provided the steps are in order. Space in a computer is even less meaningful. The concept of space may be applied to memory storage, which usually expands or contracts as needed, and to the addresses used to identify specific storage locations, but that is clearly not physical space. Thus, it became an interesting question in the present study to ask why time and space were so central to human experience while being so incidental to computers that were supposed to perform human tasks.

One can think of time and space as resources, like farming and the wheel, that people need and computers don’t. Humans share time and space with other forms of life, so to surmise why temporal and spatial resources became so important to humans we looked at the currently accepted history of life on this planet. In very general terms, the current evidence suggests that the Earth was formed about 4.5 Ga ago and life began to emerge at least 3.7 Ga ago (Dodd, 2017). The first living organisms appear to have captured energy from hydrothermal vents on our still-cooling planet and used it to construct single cells without nuclei. There was water and a sparse atmosphere of mainly carbon dioxide but no free oxygen. Life's earliest activity of which there is a record today was its evolution into species, some of which had nuclei and resembled modern bacteria.

Evolution requires an understanding of time. It requires that understanding in the same way that a digital computer must emulate a time dimension—to define "before" and "after." Evolution and its consequence, speciation*,* are both driven by the combination of two events in an organism's life: reproduction and dying. When an organism reproduces before dying it may become a contributor to evolution. If it has a suitable genetic mechanism it may help define a species. If it dies before reproducing it plays little or no part in evolution.

It is clear that speciation, with different species trying to improve their adaptations to specific habitats, is a winning strategy for life to populate a new planet. We might conclude that time, which makes such speciation possible, is life's oldest and most general adaptation.

An organism that knows only a time dimension may reproduce itself by fission or cloning; but to establish an evolving species, individual organisms must change from generation to generation, and those changes must be tested by propagating them throughout the species. This suggests genetic recombination, which requires the creation of set of digital instructions for building new creatures. On Earth, life's crucial breakthrough appears to have been the development of the DNA molecule, which stores a set of instructions for building new organisms by representing time spatially. By reading codons—groups of amino acids strung spatially along the length of DNA genes—an organism can execute the time-sequential actions necessary to manufacture proteins. The positions of certain codons in one dimension of space represent the serial steps in time required to synthesize each specific molecule.

A digital reality with one dimension of space may be adequate for reading DNA and also for feeding oneself by random encounters with heat differentials in one's environment. But around 3.1 Ga ago life on Earth began an evolutionary breakthrough: using photosynthesis. At the time, a few phototrophic microbes could capture energy from sunlight, but they did so inefficiently and did not extract carbon from the environment. Solar photosynthesis by means of chlorophyll ultimately evolved into a versatile chemical factory that uses the energy of sunlight to break carbon dioxide and water into their elements, while synthesizing a variety of handy organic molecules and supplying our atmosphere with oxygen. This last feature of photosynthesis—that the primary waste product of its reduction of carbon dioxide is oxygen—made possible the evolution of aerobic organisms and the mitochondria that today nourish mobile animals. Though the species *Homo sapiens* appeared on Earth only during the last 0.2% of this history, it inherited a foundational bias toward supporting photosynthesis in its DNA.

As plants began to fill the terrestrial biome, practical photosynthesis—life depending for its entire subsistence on the heat differential between a cooling planet and a distant Sun—required an understanding of additional dimensions in space. Moreover, that understanding did not merely have to comprehend an invariant delivery path for the radiant energy, it also had to provide for the fact that the planet whirled on its axis and orbited around the Sun. From the viewpoint of a plant on the planet's surface the Sun frequently appeared and disappeared for varying lengths of time as well as rising and falling in altitude during the planet's orbit.

The evidence today is thin, but it appears that sometime between 1 Ga and 200 Ma ago life on Earth began to encode RNA and DNA to carry its species forward by means of digital instructions instead of physically through fission-like processes. Were an ancient computer programmer tasked by evolution to encode the means by which plants tracked the source of their energy, it would have been clear that any practical encoding would have to treat time and space as a single framework—as indeed it became clear to Einstein, Minkowski, and Lorentz at the beginning of the 20th century. Such an encoding could treat the propagation of radiant energy as a vector in spacetime that was invariant with respect to the vectors that described the movements of the Sun, the Earth, and any evolving species thereon. We suggest that this was the origin of the invariance of the speed of light that is a unique feature of Relativity theory. It was a digital "hack" that evolved during the dawn of life to support the inheritance of photosynthetic energy harvesting algorithms through DNA code. The hack may also have included the interpretation of gravity as a curvature in spacetime so plants could easily determine which spatial vector was orthogonal to their planet's mass.

7. Metaverse ontology

Although DR theory is mainly useful in analyzing metaverse epistemics, it tends to imply an ontology that may be of interest in traditional philosophy. If a metaverse were to be programmed to describe the existence of which it is a part, freed of preconceptions instilled by its human designers, it might construct a model such as the following.

First off, a metaverse would not need to base its ontology on a universal existence of discrete objects in empty space and events ordered by time. Such an ontology can be treated as a result of digitization, not as a description of its source. We know that when we digitize inorganic existence some aspects of it become mass, others become energy, and that these two aspects evoke a force, gravity, that affects everything.

The problem is that science has yet to come up with an imaginable description of what mass, energy, and gravity really are. The only way science has yet been able to define these entities is by predicting what they will do in various digital models (Panek, 2019). Such models introduce time and space; but there is good evidence, produced by creative thinkers such as Kurt Gödel (Gödel, 1949) and by the practical uses of quantum entanglement (Matson, 2012), that time and space are needed only to help our understanding and not because they are properties of inanimate existence. As an alternate, DR theory can make a case that life needed time ordering, spatial definition, and a proprioception of gravity to support the observed evolution of photosynthesis.

William Whewell, writing at a time when natural philosophers assumed that reality was the fixed creation of a higher Power, found objectivity in what he called "hard facts." The job of the scientist was to dig out those facts empirically and then interpret them. But today—nearly two hundred years later—hard facts have turned out to be remarkably elusive, particularly in areas such as cosmology and psychology. Exploring metaverses that we have constructed with artificial ontologies may help us understand how we actually understand the existence of which we are a part and how our understanding may be improved.

8. Conclusions

Digital Reality theory may be summarized in seven words: *Life understands existence by constructing digital realities* (Towner, 2020). Computers also construct digital realities when they emulate life in metaverses, including human life. But in constructing realities, computers can be programmed to vary their foundational assumptions, which living things usually cannot do. This means that a computer-driven metaverse can use set theory instead of numerical analysis to understand the world, and it can free itself from the epistemological biases that humans inherited from life's evolution on planet Earth.

A central point emerging from our study of how metaverse epistemology might work is that human knowledge is mainly stored digitally. Analog signals may impinge on us, but by the time their information reaches our neurological centers they are digitized. That does not mean that our A-to-D digitizing algorithms are simple—for example, converting a video raster into the reality of a movie requires complex processing—but that they are necessary. We surmise that the reason for this is because we are decision-making animals.

Because humans store data digitally, we conclude that set theory is a useful tool for understanding human knowledge. When we treat objects of knowledge as sets, we immediately enter a long history of Western philosophy. We find that human knowledge naturally divides into behavioral, physical, and ideal types, roughly corresponding to mind, matter, and universals. The Cartesian mind-body problem can be resolved, however, because the foundational sets on which it is based are related one to another through axiomatic powerset operations.

On the subject of evolutionary biases in human epistemology, we conclude that our experiences of time, space, and gravitation—passed to us genetically through our DNA—were mainly determined much earlier, during the billion years in the evolution of terrestrial life when plants were life's dominant form. Hence, we conclude that time and space are adaptations of terrestrial life that support photodynamic energy harvesting—they are not innate features of existence. They are hallmarks of life's acts of set construction and may be described abstractly as sets. This conclusion suggests that non-photodynamic metaverses might help us gain perspective on certain issues in human epistemology, including the following:

8.1. The event horizon called the "big bang" may be an artifact of our attempt to extrapolate time before the appearance of life on Earth. A computer in a metaverse could describe the scenario postulated to occur at that "zero time" in terms of the evolution of life's ability to digitize analog measurements of photodynamic data, not as a sequence of unique events taking place in the physical universe.

8.2. Computers in a metaverse might analyze spatial cosmological data in such a way that the data exposes the "dark" mass and energy that current astrophysics finds to exist. Viewing the universe from a more comprehensive standpoint is difficult for us in our naturally evolved habitat but it might be easier in a metaverse.

8.3. Although photosynthetic life on Earth probably started as floating cells in the paleo-archaean ocean, it eventually discovered the advantages of using wet soil or marshland as a habitat. The processes of locating our Sun from solid land, as well as anchoring in that land and extracting water and nutrients from it, required that plants understand up and down as stimuli. To do this, it appears that plant life on Earth evolved a sense of the phenomenon that we understand as gravity and which Einstein interpreted as a curvature of spacetime.

8.4 The foregoing adaptations and biases introduced during the evolution of humankind, uncovered by the study documented here, warrant characterizing some of the current foundations of human knowledge as planet-specific. The foundational changes need to give a metaverse a more neutral viewpoint should be relatively easy to determine and code into the software of its computers. If the resulting knowledge bases are programmed just to account for the solar-specific bias in today's spacetime observations, the resulting epistemics will be more universal and computer-friendly. These changes may allow a metaverse technology to explore areas of knowledge—particularly in cosmology—that are presently difficult to access.

9. Experimental verification

The analysis presented here suggests it may be possible to provide experimental support for the hypothesis that time and space, as we know them, are epistemic adaptations evolved to harvest energy from a distant source that moves relative to our habitat. One way to test this hypothesis would be to program the foundation of a metaverse to harvest energy locally from sources that are stationary with respect to its habitat—sources such as local hot spots. Call that metaverse's universe a "non-relativistic reality." Then perform an assay of the cosmos within that metaverse, using tools specifically designed for its energy system. Any substantive differences between that reality and the reality currently understood by human sensation would presumably be artifacts of life on Earth's evolved perceptions of spacetime (which were developed and digitized during the era when that life was primarily dependent on photosynthesis), not of the inherent nature of existence.

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Ethics declarations

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