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Review

The cellular universe: A new cosmological model based on the holographic principle

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Human knowledge of the universe is largely incomplete. Rapid progress in the understanding of cosmology is anticipated with the development of new strategies of examination. Among these strategies, holographic modeling may be the next great revolution that awaits cosmology. This comparative review, which is the first of its kind, describes the universe from the perspective of cell biology, focusing on theoretical and observational conceptualizations of cosmic history. This holographic strategy presents us with a natural, understandable, and reasonably expanding universe; in fact, nearly all that exists in the macrouniverse is mirrored in a biological cell as a microuniverse. Simply put, the universe can be pictured as a cell. Such holographic simulation may be helpful for designing better hypotheses for cosmological research projects, especially for those that require significant commitment of time and finances. It may also impart holistic insights to any researcher interested in the inner working of the cosmos.

Key words: Cosmology, cosmological model, holographic principles, dark energy.

INTRODUCTION

Mankind has sought to understand the cosmos since ancient times. However, even for modern observers there are fundamental limitations that are posed to our understanding. We are finite beings, limited by our experiences and circumstances, and we occupy a specific place in space and time. Today's cosmological perspective is comparable to imagining the overall shape of the body when it is observed from the inside of one of our cells. The uniqueness of our universe is essentially an ultimate limit on our ability to test cosmological theories experimentally (Ellis, 1999). The speed of light puts another compromising and unbreakable restriction on our ability to probe and observe the whole universe. Particle horizons also represent a limit to observations (Ellis, 1999; Bekenstein, 2003); for example, it is impossible to determine what is inside a black hole (Bekenstein, 2003). The standard cosmological model is the "Big Bang," and while the evidence supporting that model is enormous, it is not without problems (Duprat et al., 1998; Bennett, 2006; Kragh, 2007). As a result cosmologists are still unable to explain all cosmological phenomena purely on the basis of known conventional forms of energy, for example those related to the accelerating expansion of the universe, and therefore they invoke a yet unexplored form of energy called dark energy (Kirshner, 2003). It has been shown that the presence of dark energy would make cosmology as a science basically impossible for an observer in the distant future. Understanding dark energy has thus become the central problem in modern cosmology. An alternative to the role of dark energy is general relativity, and although this model has been strongly tested within the solar system and the surrounding space, it has not been proven on scales roughly the size of the current universe (Krauss and Scherrer, 2008; Genovese et al., 2009). Furthermore, there is not a reliable physical framework to interpret the behavior of the very early universe. Finally, we know that outside the cosmic horizon is the invisible

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part of the universe which is substantially, maybe enormously larger, than the visible universe (Høg, 2003). To avoid these numerous observational limitations, cosmology could benefit from an accurate and accessible simulation of the universe. Among these is holographic modeling, which could be the next crucial strategy to facilitate and promote understanding of the universe in general.

THE HOLOGRAPHIC UNIVERSE

A surprising theory called the holographic principle proposes that the universe is like a hologram. In principle, every point of a hologram contains all the information possessed by the whole (Oort, 1970; Bekenstein, 2003; Robbins, 2006; Anjamrooz, 2011). If we try to take apart something made holographically, we will not get the pieces of which it is constructed, but instead only smaller wholes (Bohm, 1973; Talbot, 1991; Anjamrooz, 2011). Theoretical results about black holes suggest that the universe is in some sense a gigantic holographic structure (Bekenstein, 2003). In a holographic structure, the form of an object is fully enfolded in every point on a two dimensional surface, so perhaps in a similar manner the form of our universe is completely enfolded in a biological cell. Some cosmologists believe that the model of an open universe is ruled out at 99.9% confidence because it indicates that the observed pattern of cosmic microwave background fluctuations is extremely unlikely, a one-in-a thousand coincidence occurring in only 0.1% of all Hubble volumes (Tegmark, 2003). If the geometry of the observable universe exactly equals the critical density, then we live in a flat universe (Voit, 2005). But this model is not entirely satisfying because the mean density of baryonic matter is about 15% of the total amount of matter, and we can observe baryonic matter only (Høg, 2003; Voit, 2005). Thus, if we imagine the universe as a sphere, we observe three dimensions. The surface (outer boundary) of the sphere has two dimensions. The third dimension of the universe is the radius of the sphere, which can be drawn inward from any point on the surface of the sphere to its central point. This central point is an analogy for the Big Bang – the center of the universe. This third dimension, according to the holographic principle, is represented holographically on the surface of the sphere. The eukaryotic cell as a biological model for cosmology is located on the outer boundary of the universe. The interior volume or bulk of the sphere can be imagined as having a field at the boundary of the sphere that describes all of the particles of matter and vibrations of energy within the sphere (Bekenstein, 1981; Bekenstein, 2003). So, our universe, which we perceive to have three spatial dimensions, might instead be "written" holographically on a two-dimensional surface (Bekenstein, 2003). This perspective is a surprising clue to the ultimate theory of reality. It is like seeing the image of a three-dimensional object in a two-dimensional mirror. The image of that object has a non-local property, so that any fragment of a shattered mirror also will show the whole image of the three-dimensional object (Anjamrooz, 2011). In the holographic scenario, the "whole in every part" nature of a hologram (Raychaudhury, 2005; Sharma, 2006; Kragh, 2008) provides us with an entirely new way of understanding cosmology. If we can, as William Blake memorably penned, "see a world in a grain of sand" (Bekenstein, 2003), then a biological cell can become a small universe in itself, and we can begin to see cosmology through cell biology. In other words, according to what is referred to as the holographic principle, studying cellular morphology and behavior can help us understand universal development.

STRUCTURE OF THE CELLULAR UNIVERSE

For more than 35 years, black hole physics has been one of the most active fields of research in both classical and quantum gravity (Sultana and Dyer, 2005). The cellular model of the universe presumes a black-hole centered universe which is, roughly speaking, similar to a biological cell in many surprising aspects. Since a black hole is spherical, it resembles the cell nucleus in shape (DiNunno and Matzner, 2010). In addition, similar to the two-layered nuclear membrane in eukaryotic cells, any black hole has two event horizons, the outer horizon and inner horizon (Fujiwara et al., 2009; Ren, 2009). The horizon is a spherical surface that marks the boundary of the black hole. The laws of relativity prevent anything that goes into a black hole from coming out again, at least within classical physics (Bekenstein, 2003; DiNunno and Matzner, 2010). We conjecture it is analogous to the nuclear membrane, which prevents mixing of nucleoplasm and cytoplasm. In addition, trafficking of proteins and nucleic acids in or out of the cell nucleus is restricted by the nuclear membrane (Ploski et al., 2004). In 1974 the British theoretical physicist, Stephen Hawking, demonstrated that a black hole spontaneously emits electromagnetic radiation, now known as Hawking radiation, through a quantum process (Bekenstein, 2003). In 1920, the Russian embryologist, Alexander Gurwitsch, also demonstrated that the nucleus of each living cell emits small pockets of electromagnetic radiation (Bischof, 2005).

The cell nucleus is a big dark spot in the center of the cell. It is the densest part of the cell, which contains DNA and acts like the brain of the cell, much like a quantum system (Pattee, 1979). It is possible that, in a similar manner, a huge black hole constitutes the "brain" of the universe (Sheppard, 2000). Studies of black holes show that they are immensely dense concentrations of mass, which could potentially function like quantum computers (Lloyd, 2000, 2006; Bekenstein, 2003). Generally,

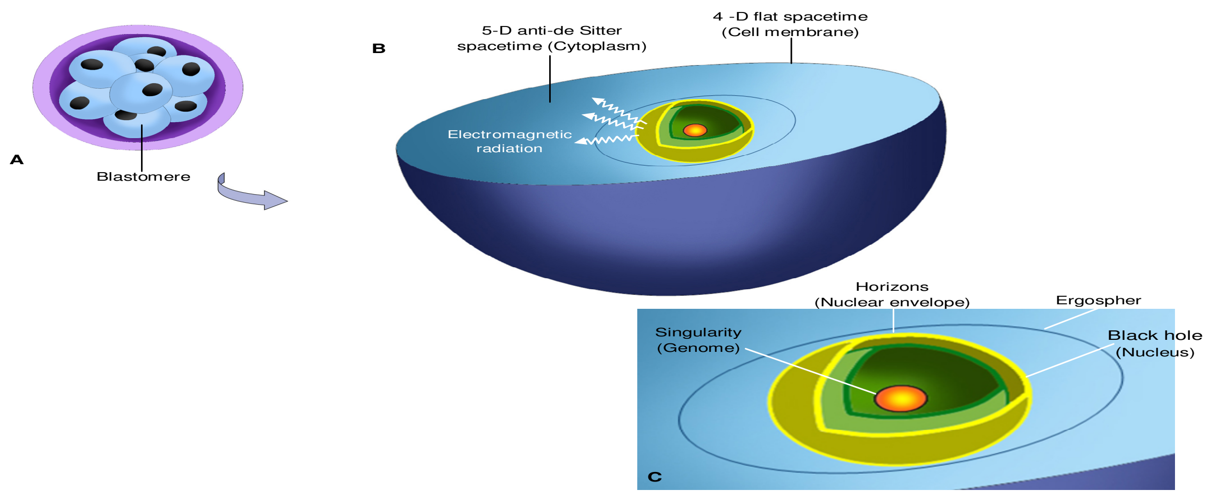

Figure 1. The cellular universe model. (A) Multi-cell embryo correlate to the multi-universe, (B) A black hole in five-dimensional space-time is equivalent to the cell nucleus in the cytoplasm of a blastomere, (C) Enlargement of the area outlined with ergosphere in B (modified from Bekenstein, 2003).

information and consciousness has a quantum basis. Many researchers have conjectured that quantum effects in the brain are crucial for explaining psychological phenomena, including consciousness (Alfinito and Vitiello, 2000). Singularity is predicted to exist at the center of a black hole, where so much mass becomes concentrated in an infinitesimally small area of volume (Barkana, 2006). The universe expanded to its present state from a similar singularity in space-time (Kragh, 2007). It is believed that DNA's principle function is to provide a template for an organism's physical structure (Beck and Colli, 2003). Hence, we call this singularity, "black hole's genome." Perhaps, just like a genome of DNA, the singularity of the black hole is not a point-mass (Zheng et al., 2004; Crothers, 2006).

In string theory, holography is a special case of a more general duality between open and closed strings. This duality implies that the dynamics of open strings contain the dynamics of closed strings (Das, 2008). String theory replaces the point particle with something that does not inscribe a point, and as such avoids the singularity problem. Moreover, based on the brane-world scenario, the point-like elementary particles we see might be the ends of open strings terminating on our brane. It has been observed that chromatins are usually attached to

the nuclear membrane (Skaer and Whytock, 1975). Equally, the endpoints of the open strings attach to the black-hole horizon (Ellis et al., 1997).

Superstring theory proposes that the universe is made of strings. In the holographic viewpoint, amino acid strings are the building blocks of the cells as well, forming the main functional components of cells (Campbell, 2008). Roughly speaking, the string-like DNA in the rotating nucleus is similar to Kerr's model, in which string-like singularity appears in the rotating black hole (Burinskii, 2000; Lee et al., 2005; Ji et al., 2007). As illustrated in Figure 1, a massive black hole exists in a space-time and rotates around a central axis similar to the nuclear rotation in the cytoplasm, which is essential during nucleus positioning for eukaryotic cell development (Bekenstein, 2003; Lee et al., 2005).

Like a real universe, the biological cell is a four-dimensional system: it has volume and extends in time (Bekenstein, 2003; Jorgensen et al., 2007; Edgar and Kim, 2009). A class of concrete examples of the holographic principle at work involves so-called de Sitter space-times. In this model, the universe expands at an accelerating rate and is very highly symmetrical (Bekenstein, 2003). The cell has a spherical symmetry as well, with an exponential expansion as presented in

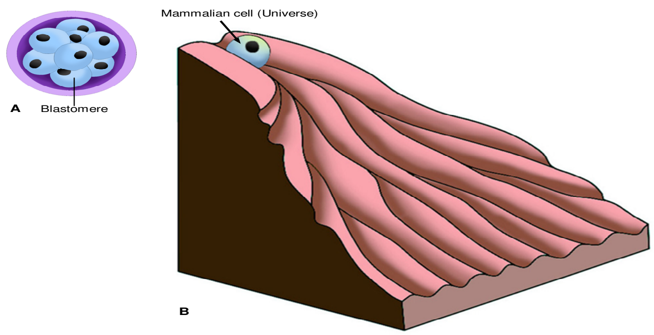

Figure 2. The landscape model of mammalian cell differentiation or multi-universes. (A) Multi-cell embryo correlate to the multi-universe, (B) the landscape model of different paths (modified from Niemann et al., 2008).

Figure 1 (Yang et al., 2006; Edgar and Kim, 2009) In 1997, cosmologists studying distant supernova explosions concluded that our universe will probably become progressively like a de Sitter model in the future (Bekenstein, 2003). The five-dimensional anti–de Sitter universe is hardly like our universe existing in four-dimensional flat space-time (Bekenstein, 2003; Tegmark, 2003). The expanding universe is space-time, filled with matter and radiation. This is holographically comparable to the cytoplasm inside the cell membrane. Furthermore, the cell size expands during the cell cycle (Jorgensen et al., 2007). Thus, it seems that the cell is experiencing space-time expansion that looks a lot like our universe.

The cell also is filled with cytosol and nucleoplasm and emits radiation (Beloussov, 2003; Bischof, 2005; Farhadi et al., 2007). A lot of work has been done (for over 30 years) on the electromagnetic field phenomena that are associated with biological processes (Miller and Webb, 2002; Beloussov, 2003; Bischof, 2005; Farhadi et al., 2007). When the sperm and the egg unite, the membrane around the egg becomes hyper-polarized. It is at this moment that the electromagnetic entity is formed. Faraday did some experimentation with animal electricity, and Galvanni (with his Galvannic cells) did experiments with animals (Miller and Webb, 2002). All living cells are continuously and spontaneously emitting biophotons in the form of ultra weak electromagnetic radiation (Beloussov, 2003; Farhadi et al., 2007). So, it was quite understandable in the growth of science to accept life as being electronic (Miller and Webb, 2002).

THERMODYNAMICS OF THE CELLULAR UNIVERSE

The second law of thermodynamics makes no distinction between living and non-living things (Udgaonkar, 2001). It states that most processes in nature are irreversible (Bekenstein, 2003). This law is also seen in developmental biology (Yakovlev et al., 1999; Niemann et al., 2008), basically, the mechanism of evolution makes the whole process irreversible (Udgaonkar, 2001). For instance, embryonic cell differentiation is irreversible, as illustrated in the landscape model of cell differentiation in Figure 2 (Toyooka et al., 2008). A human zygote can “bang” or “explode” into a multi-cellular embryo, inside which many somatic cells explode again. In addition, a long-held dogma is that mammalian somatic cell differentiation is irreversible and terminates in cell death or, in our terminology, a “tiny crunch” (Yakovlev et al., 1999; Niemann et al., 2008). This is similar to the cyclic model of the universe proposed by Paul et al., in which the universe undergoes an endless sequence of cosmic epochs that begin with a “bang” and end in a ”crunch” (Steinhardt and Turok, 2002; Tegmark, 2003).

The holographic principle arose through the formulation of the entropy and energy relations of black holes, according to the generalized second law of thermodynamics (Bekenstein, 1974). Entropy is equivalent to information and provides a basis for more stringent information measures as well. The change in entropy is always positive, and in real processes it always increases and never decreases. Every isolated system moves towards a state of maximum entropy. The entropy of a black hole is proportional to the area of its expanding event horizon (Udgaonkar, 2001; Bekenstein, 2003; Sultana and Dyer, 2005). The universe is presumably an isolated system, whose entropy can never decrease (Udgaonkar, 2001). In animal cells, the nuclear envelope also expands during the cell cycle to accommodate DNA changes. The primary role of DNA is information storage (Sheppard, 2000; Jorgensen et al., 2007). Although it is restricted mainly to the nucleus, the mitochondria in the cytoplasm also contain DNA (Stanlis and McIntosh, 2003). Hence, the cell's entire DNA is restricted by the cell membrane. Equally, the universal entropy boundary limits the amount of information at the holographic surface of the universe (Bekenstein, 1981; Bekenstein 2003). Heat death is a possible final thermodynamic state of the universe, in which the universe will go into infinity and reach maximum entropy (Kutrovátz, 2001). By comparing the definitions of thermodynamic entropy and information quantity, Luo et al. showed that information flow is related to entropy flow. Since information quantity is a projection of thermodynamic entropy, the entropy flow should be the carrier of the information flow. Hence, the entropy flow from a normal to a cancerous cell carries the information of the healthy cell, while the entropy flow in the opposite direction (an "invasion of malignancy") carries the information of the cancerous cell. This is why Luo et al. emphasize the meaning of the entropy flow direction (Luo et al., 2006). As a result, it is possible that the ability for expansion flows from our universe to the next one.

DARK ENERGY IN THE CELLULAR UNIVERSE

Hubble found that the universe is expanding now (Rix, 1999). Most cosmologists today concur that our universe resembles a "Friedmann-Robertson-Walker" universe, one that is infinite, has no boundary, and will go on expanding *ad infinitum* (Bekenstein, 2003; Genovese et al., 2009). Accelerating models of the universe posit the existence of a ubiquitous energy field of unknown composition that comprises about 73% of all mass-energy and yet that can only be detected through subtle effects. This mysterious energy field with negative pressure has been called "dark energy" (Genovese et al., 2009). This expanding energy can be called the "universe's soul". Similarly, we don't know what the human soul is yet, but we have clearly seen its effects. Aristotle and medieval philosophers such as Thomas Aquinas regarded the concept of *eidos* as closely connected with the notion of a *forma* or "soul", which was believed to have the capability of expansion and is responsible for shaping matter into the recognizable form of a living organism (Mauron, 2001). Hence, it drives us forward along our own path of evolution (Glannon, 2000; Nash, 2003). Philosophically, the soul has infinite energy (Jaini, 2003); it is possible that the human soul is made of dark energy. There exists the belief that it is a minuscule part of the unconverted energy of God, and thus we are a reflection of God. Man's soul has unlimited potential, which asserts its survival after death (Druart, 2000; Glannon, 2000). As can be observed in Figure 3, death, which sunders body and soul, returns the soul to its natural state (Glannon, 2000).

Einstein showed with his famous equation, $E=mc^2$, that matter and energy are considered to be two forms of the same thing (Bekenstein, 2003). Dark matter and dark energy seem to make up most of the mass of the universe, much like the body and soul make up a human being. Therefore, based on the holographic principle, it is possible that the physical universe, ordinary and dark matter, will end in a big crunch, while its metaphysical part, dark energy, will go on expanding forever as described in Figure 3. In western metaphysics, every living thing has a soul. If there is an individual soul that leaves the body at death, as most of us suppose, then it is imaginable that this individual soul is an organization of cell souls, just as the body is an organization of cells.

According to genomic metaphysics, the genome becomes the secular equivalent of the soul (Mauron, 2001, 2002). If we suppose that the soul is dark energy, then the nucleus is the location of the secular equivalent of the dark energy, controlling cell expansion and division. Observation of similar repulsive forces within biological cells was reported previously (Lieber, 1996). An important reason for exploring the relationship between nuclear volume and the cell cycle is that nucleocytoplasmic ratio usually increases in malignant neoplasms (Jorgensen et al., 2007). Equally, according to the model of the black hole universe (Zhang, 2009), if again we assume that a massive black hole is the site of the materialistic analog of dark energy, then it is responsible for universal expansion and its multiplicity.

It is clear that the nuclear size of the cell increases during the G1-phase (Jorgensen et al., 2007). In a similar manner at the macro scale, as time progresses, the universe becomes increasingly dark (Caldwell et al., 2003). Phantom energy is a hypothetical form of dark energy with an equation of state $w < -1$. If it exists, its energy density increases with time. So, before the occurrence of the "big rip," it could cause the expansion of the universe to accelerate (Caldwell et al., 2003). This increment in dark energy corresponds to energy addition during the G1 phase of the cell cycle (Warden et al., 1980). Animal cell growth is exponential during most of the cell division cycle (Edgar and Kim, 2009). The universe is expanding exponentially, as well (Rix, 1999; Johri, 2002; Bekenstein, 2003; Nagamine and Loeb, 2004). In biological cells, the size of the nuclear envelope (a correlate for an event horizon) can never decrease with time during the G1-phase. Equally the event horizon

Fig. 3.

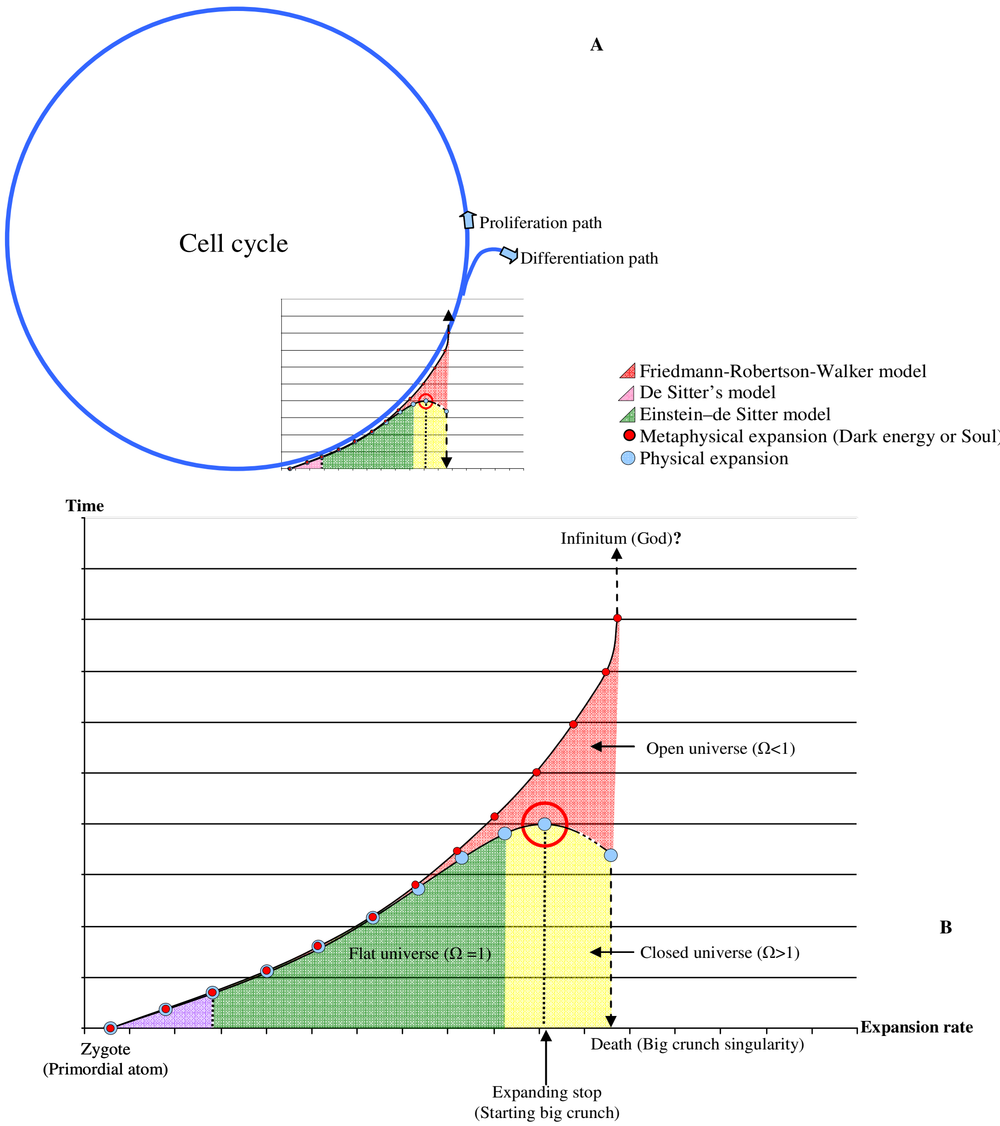

Figure 3. The ultimate fate of the universe in the cellular model. (A) the fate of cells during the cell cycle, (B) the expansion rate is plotted against time, showing different cosmological models and cell fates.

of a black hole can never decrease with time, as discovered by Hawking (1971).

THE ULTIMATE FATE OF THE CELLULAR UNIVERSE

In our approach, the universe has two different fates: the big rip and the big crunch. These are equivalent to (1) ripping up of the nuclear envelope during proliferation and (2) cell shrinkage in apoptosis, respectively (Bortner and Cidlowski, 1998; Lippincott-Schwartz, 2002). The first fate is due to a repulsive force, and the second fate is due to an attractive one, approximately like de Sitter and anti de Sitter models, respectively (Bekenstein, 2003). Through the holographic principle, it is possible to imagine the existence of two fates of different dimensions and obeying disparate physical laws. The present universe might expand in an accelerated fashion in a state described by De Sitter's model (Bekenstein, 2003), and then probably it will develop toward a state described by Einstein–de Sitter's model, in which the universe has a continually decreasing expansion rate as illustrated in the Figure 3. Apoptosis, also known as programmed cell death, is a normal physiological process. It is universally characterized by a ubiquitous characteristic called cellular shrinkage (Bortner and Cidlowski, 1998; Bortner and Cidlowski, 2003); thus, it is analogous to the big crunch (Bedford et al., 2007; Bicak, 2009). The big crunch is a hypothetical cosmological scenario for the ultimate fate of the universe, in which the universe will eventually start to collapse (Tegmark, 2003; Bedford et al., 2007; Bicak, 2009). Equally, when a biological cell dies, it undergoes a tiny crunch. However, death is the thermodynamically favored state: it represents a large increase in entropy as molecular structure yields to chaos (Udgaonkar, 2001).

Similar to what is seen in a big rip universe (Caldwell et al., 2003) and the theory of open and closed strings, or string theory (Das, 2008), a cell undergoing mitosis expands before ripping up of the nuclear envelope. Then all of the chromosomes (coiled DNA) are replicated and chromatin changes into chromosomes. The expansion phase, G1, takes up most of the cell's life. In eukaryotic cells, the cell division cycle is under size control, such that cells do not commit to division until they have grown to a certain critical size (Jorgensen et al., 2007). After DNA duplication, the nuclear envelope has been completely ripped up and allows the nuclear genome to enter into the cytoplasm and move to the opposite poles of the cell by spindle fibers (Lippincott-Schwartz, 2002). It is generally followed by cytokinesis, in which the cytoplasm of a single cell is divided to form two daughter cells.

In theory, it is possible for a singularity or a black hole's genome to escape from a black hole, similar to what which occurs during cell division. Recent models of the black-hole final state also suggest that quantum information can escape from a black hole (Sheppard, 2000). Thus the idea of reaching other universes via a black hole's interior is rather attractive, as matter that falls into a black hole in our universe could emerge and start another universe (Hod and Piran, 1998; Tegmark, 2003). In a biological cell, the nucleus also regulates cell division via DNA (Schumer and Sperling, 1968; Pannek et al., 1999; Fujiwara et al., 2009). Furthermore, a century of developments in physics has taught us that information is a crucial player in physical systems and processes (Bekenstein, 2003). It is inferable that cell expansion does not cease, but continues *ad infinitum* by creating new cells that divide again. Perhaps this process started from the first cell, and continues forever.

There are many types of cells in our body, each with its own differential and physiological properties. This is similar to the idea that there is more than one universe, each with its own laws of physics, and our universe is just one of many, as presented in Figure 2. Multiple universes arise out of several different theories, including string theory, cosmic inflation, dark energy and black hole theory (Tegmark, 2003). Biological cell proliferation also arises out of several different biological processes, including string events in the cell, cell size expansion, repulsive forces and genomic regulations (Lieber, 1996). Repeated branching would exponentially increase the number of universes over time. It is apparent that cell division results in an exponentially increasing cell population as well (Tegmark, 2003). Perhaps there is a super massive black hole in the center of the universe which functions like the cell nucleus during division. The biological model of cosmology is in agreement with the "many worlds in one" model. According to this model, there are an infinite number of copies of the universe with everything that exists on it, much like our cells each have all the necessary information to create another whole being (Koonin, 2007). Scientists successfully used this amazing finding for human cloning in the last several years (Cibelli et al., 2001). Also, the chains of connected cells that develop during some processes (for example, spermatogenesis), are comparable to multiple universal interconnections (Tegmark, 2003; Zheng et al., 2009). Another biological explanation focuses on adhesion receptors that connect cells to each other (Gimond et al., 1999).

In the quantum black hole model, the universe will be in a state of eternal inflation (Altaie, 2008). This type of inflation resembles the nuclear expansion of biological cells, which started from the first cell, extends to present day, and perhaps will continue *ad infinitum* via cell proliferation. Most astronomers believe in a big crunch universe, in which the universe culminates as a black hole singularity due to gravitational attraction. This is not possible if the universe does not have a center, as classical physics also states that physical reality is local. In an opposing viewpoint**,** some scientists believe that there is no such thing as the universe's center. Bell's theorem and Aspect's corroborating experiments have established to the satisfaction of most physicists that the universe is non-local (Laudisa, 2008). In terms of ontology, quantitative researchers think there is one reality. If there is one reality then there should be one conceptual description thereof (Stahl, 2007). Because this line of thinking is based on a property called "holographic non-locality," the biological model of the universe is in accordance with both of these paradoxical conclusions. So while our universe has a center, its center is non-local due to infinite multiple universes (Tegmark, 2003).

It now seems inescapable that quantum reality is fundamentally non-local (Allori and Zanghì, 2004; Mongan, 2007). This non-locality of the universe's center resembles the non-locality of the cell nucleus, as a micro-universe, in the multi-cellular human body.

Similar pattern is reported in mind, based on the idea of the holographic universe and the principle of non-locality (Robbins, 2006).

CONCLUSION

If the holographic principle is true, then it must be the fundamental principle of creation. Recently, considerable interest has been stimulated in explaining reality through holographic principles. The cellular universe theory is an attempt to complete the quest for unification, to formulate many of the laws of cosmology within a single biological framework. The present biological model shows some macro-micro similarities between the universe and the cell. Based on it, the entire mass of a black hole is concentrated at the universe's center, which is the singularity or the "genome" of the universe. The matter which falls into a black hole could emerge and start another universe due to the ever increasing force of dark energy or the universe's soul. Thus, there may be an infinite number of universes each with its own set of physical laws. Besides this metaphysical or infinite fate, the universe also will undergo a physical or finite fate in which it stops expanding and ultimately collapses on itself. Maybe, according to Einstein's famous equation, $E=mc^2$, metaphysical and physical fates, like matter and energy, are two convertible forms of the same thing.

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