# The Creative Universe and the Creating God

## Chapter 11. A New Perspective

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From Chapter 3 to this point, I summarized modern progress in science, emphasizing its influence on our world views. There are six characteristics of the universe that modern science has uncovered which are most important to an integrated world view. First, the universe is immensely large and very old. It is about 14 billion years old and larger than 14 billion light years in radius. Second, every part of the observable universe is interconnected and follows the same universal laws. Third, the universe evolves. As a whole, it goes through evolutionary phases. The sun and other stars evolve as they deplete their nuclear fuel. The earth also goes through physical evolutionary stages. In addition, chemical evolution, biological evolution, and cultural evolution take place on earth. Fourth, the course of the universe is not strictly determined by deterministic laws and the present condition of the universe; but, instead, its future has open possibilities. Fifth, life on earth is interconnected and inter-dependent. Sixth, fundamental physical constants have precisely the values needed to make the emergence of life possible. If one of the physical constants had a value slightly different from its actual value, the universe would not be able to generate life.

In addition to acceptance of these six important characteristics of the universe, today most scientists maintain a monistic world view; that is, special laws or substances such as "elan vital" are not necessary in order to explain life in addition to the ones that are necessary to explain physical and chemical phenomena. Life is regarded as a property emerging when matter is organized in a complex manner. By the same token, the mind/matter dualism is no longer favored: mind is regarded as a property emerging when neurons are organized in a brain in a complex manner. Unlike the above six, the acceptance of this view is not unanimous in the scientific community. Nevertheless, its wide acceptance represents a striking change from the dualisms that enjoyed popularity as bases for world views in previous centuries. In this chapter, I review how modern scientific understanding of the universe, embodied in these characteristics, influences our world view.

### *The Unity and the Interconnectedness of the Universe*

One of the fundamental characteristics of the universe is that the same natural laws apply everywhere in the universe. In other words, natural laws are universal. In Chapter 3, I explained how Copernicus made a first crack in the medieval dualism that natural phenomena are capricious on earth and orderly in heaven by proposing a heliocentric cosmology. Then, the works of Galileo and Kepler demonstrated the unity of heavenly and earthly phenomena. Finally, Newton showed that the same gravitational law applies to heavenly objects as well as terrestrial objects. Thus, the law of gravitation was first to be recognized as a universal law.

We now have evidence that all physical laws which apply on earth apply throughout the universe. Here are two examples.

Cosmic background radiation, measured by the NASA's satellite Wilkinson Microwave Anisotropy Probe (launched in June, 2001), perfectly fits the blackbody radiation curve with a temperature of 2.73 degrees Kelvin. The blackbody radiation curve was discovered by Planck (Chapter 4), and its shape is determined by the fundamental constants $c$ (the speed of light), $h$ (Planck's constant), and $k$ (Boltzmann's constant). Cosmic background radiation was emitted at the earliest epoch we can observe (about 400,000 years after the Big Bang) and from the farthest places we can observe (about 14 billion light-years away). The fact that the cosmic background radiation follows the same curve as the blackbody radiation curve determined in a laboratory on earth means that the constants $c$, $h$, and $k$ are universal constants. It also means that the physical laws involving these constants must be true everywhere and all the time.

The energy of photons emitted by each chemical element have characteristic values that are described by quantum mechanics. The fact that the spectral features of light emitted from astronomical objects ranging from nearby stars to far-away galaxies can be explained as atomic emissions means that quantum mechanics is valid everywhere. The atomic energy levels also depend on the mass and the charge of the electron (as well as on $c$ and $h$). Thus, the mass and the charge of the electron must be universal constants.

One important trend in scientific progress is the unification of natural laws. The work of Faraday showed the unity between the properties of electricity and magnetism. Maxwell identified light as electromagnetic waves. Carnot and Joule demonstrated the conservation of energy, and Einstein showed the equivalence of mass and energy. Today, the electromagnetic interaction and weak interaction are regarded as two aspects of the electro-weak interaction. The grand unified theory attempts to unify the electro-weak interaction and the strong interaction into one interaction.

We have also learned that the universe is immensely large and very old. The universe is not just simply big and old, but every part of the universe is intimately connected to the rest of the universe. This view is consonant with ancient East Asian philosophies. Not only the expansion rate of the universe but also the formation of galaxies and stars is affected by the overall density of the universe. The universe as a whole has a history: all parts of it went through the same evolutionary phases, and the large-scale characteristics of the universe in any given epoch were the same everywhere. Protons and neutrons, the building blocks of atomic nuclei, were synthesized when the universe was only a few minutes old. Soon after that, helium nuclei were forged from neutrons and protons. Furthermore, as I discussed in Chapter 10, the values of the fundamental physical constants are intimately connected to the existence of life on earth.

### *The Universe Fine-Tuned for Life*

As I discussed in Chapter 10, if the value of any of the fundamental physical constants were even slightly different from its actual value, the universe would not be able to generate life. A universe may exist that has the same set of natural laws as ours but fundamental constants with different values. Many scientists find no logical reason to deny such a possibility. But such a universe, if it exists, would be barren. Considering that life is a phenomenon emerging at a scale far removed from the subatomic scale and the cosmological scale, the fact that the values of fundamental constants and the cosmological characteristics of our universe are precisely those needed to allow the emergence of life is so unlikely to be due to chance and so awesome that it begs an explanation. John Wheeler said that the universe seemed to be adapted for humanity:[1]

> It is not only that man is adapted to the universe. The universe is adapted to man. Imagine a universe in which one or another of the fundamental dimensionless constants of physics is altered by a few percent one way or the other. Man could never come into being in such a universe. That is the central point of the anthropic principle. According to this principle, a life-giving factor lies at the center of the whole machinery and design of the world.

Here we find the word "design," which has been expelled from biological scholarship by the biologists. Here we also find the word "anthropic," which means "related to human beings" or "related to the existence of human beings." The anthropic principle posits that the existence of human beings provides a clue to the understanding of the properties of our environment. We can answer many questions regarding the properties of the earth and the solar system by using the anthropic principle. For example, we can answer the question "Why is the solar system so old?" The solar system should be old enough to allow the emergence of humans. If the solar system were not old, we would not be here to pose that question. Why is the climate on earth just right for human habitation? If the climate were not right for humans, we would not have evolved here. We can use the anthropic principle in the cosmic context. The question "Why is the universe very old?" is explained by our existence. It takes a long time for intelligent life to emerge because long evolutionary processes—cosmic evolution, stellar evolution, chemical evolution, and biological evolution—are prerequisites for the emergence of intelligent life in the universe. The anthropic principle used in the above examples is called the *weak anthropic principle*.

If we apply the weak anthropic principle to the question "Why is the universe fine-tuned for life?" we get the following answer, which is not satisfactory. We would not be here to pose the question, if it were otherwise. The anthropic principle was first used in the cosmological context by Brandon Carter.[2] According to him, we need a *strong anthropic principle*, which can be stated: "The universe must be such as to admit the creation of observers within it at some stage." Unlike the weak anthropic principle, the strong anthropic principle claims that the existence of the universe is contingent upon the existence of *intelligent observers*.

There are three ways to interpret the fine-tuning of fundamental constants. First, they were fine-tuned by an omniscient God. Second, there exist a very large number of universes with different values of fundamental constants, and we are here because this universe *happens to be* suitable for the development of intelligent life. Third, there must be fundamental laws which would show that the fundamental constants, which seem to be independent, are actually interrelated and have their observed values by logical necessity. Let us discuss these one by one.

According to the first interpretation, at the time of the creation, the omniscient God chose the values of the fundamental physical constants with such foresight that the emergence of intelligent life was possible. The argument that the whole universe has been designed is fundamentally different from the old design argument, which posits that living organisms and their organs were designed by the Creator. The old design argument was refuted by the discovery that natural selection can mimic apparent design in organisms.

As an alternative to God's design in the creation of the universe, one can assume that our universe is just one of universes that are suitable for life among a large number of universes. There are three variations of the many-universe interpretation. The first is that there are many parallel universes, each being separate and independent from the others. The second is that there are many sequential universes. In the cyclic-universe hypothesis of John Wheeler, a new set of physical laws and a new set of physical constants are chosen randomly at each big bang. The third variation is that there are many domains in the huge universe, and fundamental constants may vary from one domain to another. We cannot detect other domains, because they are much farther away than 14 billion light years.[3]

Some theorists who propose many-universe interpretations interpret the strong anthropic principle as follows: Many universes come into existence by themselves, with all kinds of physical laws and various combinations of values of physical constants. (Here the present tense is used because we cannot establish temporal order among different universes.) Almost all of them are barren, being unable to produce life. But a few of them are suitable for the development of life. Only those universes that, during their lifetimes, produce intelligent observers that can ponder the mystery of their own universe attain the status of real existence. Our universe is obviously one of them. The universes that do not produce intelligent observers do not really exist because there is no one to recognize their existence. (Proponents of this argument are atheists. Therefore, there is no God who can observe and recognize these barren universes.) Intelligent beings are a part of the universe, because they are formed from the matter within it. Therefore, the cognition of the universe by its intelligent inhabitants is self-cognition by the universe. Reminding ouselves of Descartes's famous phrase "I think; therefore, I am," we can imagine the universe thinking, "I self-cognize; therefore, I am."

Some scientists are more willing to accept the existence of a large number of universes than the existence of God because they want to go as far as possible without invoking God. Can the many-universe interpretations be a firm basis for atheism? According to Ian Barbour,[4] the atheistic interpretation of the many-universe hypothesis relies on the interpretation of chance as antithetical to providence. However, as we discuss in Chapter 15, chance is not antithetical to providence but is God's way of fully exploring the potential of the universe (or universes). One may reason that the God who creates a very large number of universes in order to get a few habitable universes is not very powerful. But isn't the ability to create a large number of universes as powerful as, if not more powerful than, the ability to create one and only habitable universe? One may regard creating a very large number of universes to get a few habitable universes as wasteful. However, is it not more wasteful, if God has abilities He does not use?

In selecting between God's design and the many universes theory, one may use the criterion of Ockham's razor. According to it, the simplest explanation that is compatible with the observed facts is the best one. Which is simpler: the existence of a large number of universes that can neither be detected nor proven or the existence of an omniscient God's foresight and design in the creation of our universe? Many people, including me, think that God's omniscience is a simpler explanation than the hypothesis of a large number of universes.[5]

Let us consider the third interpretation: fundamental constants are interrelated such that they have the observed values. It is also a speculative line of thought, because we have not yet found such relations. I personally imagine it plausible that some of the fundamental constants may turn out to be interconnected, but it is unlikely that all of them are so. But even if this interpretation proves true, it is all the more awesome that such fundamental natural laws and a universe obeying them came into being.

Scientists who propose many parallel universes rely on the hypothetical existence of hyperspace-time continuum within which quantum mechanical laws govern the generation of many universes. Quantum mechanics is applicable within the space-time continuum of our universe. It is doubtful whether the hyperspace-time continuum exists and whether we can extrapolate quantum mechanical principles to it. The scientists who subscribe to the third interpretation also rely on the existence of natural laws. Can natural laws be a substitute for God? Natural laws are expressible by equations, which is an amazing fact. Who devised these equations? The mere existence of such equations does not ordain the existence of a universe obeying them. Borrowing Stephen Hawking's expression,[6] we may ask, "Who breathed fire into these equations?"

It is interesting to note here that, after the Copernican revolution, the status of human beings in the universe became increasingly less significant. First, the earth was dethroned from the center of the universe. Then, the sun was found to be in the outskirts of the Milky Way Galaxy instead of at its center. The world we live in has turned out to be a small planet circling around an ordinary star, which is one of hundreds of billions of stars in the Milky Way Galaxy. The Milky Way has also turned out to be one of billions and billions of galaxies in the universe, which could be infinitely large. As the scope of the observable universe has increased, our significance in its vastness has decreased relatively. But now, as we consider the anthropic principle, the existence of human beings suddenly takes the center stage again: If we accept the hypothesis of a large number of universes, intelligent observers (human beings in our case) are the ones who establish the real existence of the universe, by recognizing it. If we accept an omniscient God, He designed and created the universe in order to make the development of intelligent creatures possible.

*The Evolutionary Universe*

One look at the Grand Canyon reminds us of the power of erosion, not to mention the majestic beauty of its effect. Over the millions of years since this region evolved as a part of North America, the Colorado River relentlessly carried away soil to the Gulf of California, while the land was being uplifted. In this way, the most spectacular canyon in the world was carved out to depths exceeding a mile. Without a renewal process of the land, all the land on earth would have been eroded away a long time ago, and the earth would be completely covered by water. The renewal process counterbalancing the erosion is plate tectonics, which was discussed in Chapter 5.

As physical environments continuously change, organisms have to adapt to the changes in their environments. Organisms produce more offspring than can be supported by the limited resources of the environment. Over-production of offspring is much more evident in simple animals such as fishes and insects. A single fish produces millions of eggs at a time. Flowering plants also produce large numbers of seeds. Of the large numbers of offspring, the ones that are better adapted to the environment have better chances of survival. The survival of the fittest is a natural consequence of over-production and natural selection. As the species of organisms living in the same ecosystem change, the resulting change in the ecosystem puts additional pressure on other inhabitants. Thus, organisms living in the same ecosystem co-evolve. As the predators develop better hunting skills, the prey develop better defense mechanisms. If one species develops more efficient growth and reproduction mechanisms, competing species have to keep pace with it. Not only competitive instinctions but also elaborate collaborations between species are developed for survival.

Natural selection works at a slow pace, but artificial selection changes organisms rapidly. Artificial selection, that is, human intervention, affects the evolution of domesticated animals and agricultural crops and vegetables. Artificial selection also affects the evolution of insects regarded as pests because continued use of a particular insecticide "selects" the insects that are resistant to it.

In the game of survival of the fittest, individual organisms do not make conscious decisions to enhance the survivability of their offspring. Insects do not decide to produce insecticide-resistant offspring. Some are born with the desired trait. And the next round of application of the same insecticide selects the ones that have developed resistance to it by eliminating the ones without such resistance. Such rapid adaptation by insects is possible because they produce a very large number of offspring. Fish which ended up in a dark cave by chance did not decide to produce blind offspring. Once in a great while, a blind fish was born. In bright environments, blind fish would not survive very long. But in dark caves, not only have they a chance to survive but they have a better chance to survive than the fellows which maintain eye sight unnecessary in the dark environment.

In the twentieth century, scientists have learned that stars, including the sun, go through evolutionary stages. While in the main-sequence stage, stars radiate the energy they produce by combining protons into helium nuclei. By the time the helium nuclei in the core are converted into carbon nuclei, energy generation rates become much higher, and the stars adjust to the change by becoming red giants. After depleting all their nuclear fuel, stars collapse to white dwarfs, neutron stars, or black holes, depending on their masses. The sun will stay on the main-sequence stage for about five billion years from now, and then it will turn into a red giant, making the earth scorchingly hot.

Not only stars and galaxies go through evolutionary stages, but the entire universe goes through evolutionary stages as well. In the beginning, the universe was incredibly hot and dense, and exotic particles and very energetic photons incessantly collided with each other. Such collisions produced pairs, each pair having an exotic particle and a partner antiparticle. At the same time, particles and their antimatter partners were annihilated when they collided with each other. The universe expanded at an enormous speed for reasons we do not understand. It cooled as the universe expanded, and as it cooled, exotic particles and their antiparticles were annihilated when particle-antiparticle pairs met. But exotic particles were no longer produced because the energies of photons and particles were no longer high enough. Soon, ordinary particles such as protons, neutrons, and electrons became the main constituents of ordinary matter. Some of the protons and neutrons combined to form helium, and the remaining free neutrons decayed. (Free neutrons not bound in atomic nuclei decay into a proton, a positron, and a neutrino.)

After the particle evolution in the beginning, galaxies and stars were formed as the universe expanded. Even today the universe is expanding; it will do so forever, according to our current understanding. More details of cosmic and stellar evolution were discussed in Chapters 6 and 7.

### *The Universe of Open Possibilities*

As I discussed in Chapter 4, the recent advancement of science has made determinism untenable. Even so, some people cling to the comfort offered by the deterministic universe, as Einstein did. George Bernard Shaw also expressed his longing for the deterministic universe.[7]

> The universe of Isaac Newton, which has been an impregnable citadel of modern civilization for three hundred years, has crumbled like the walls of Jericho before the criticism of Einstein. Newton's universe was the stronghold of rational Determinism . . . Everything happened because it must: the commandments were erased from the tables of law; and in their place came the cosmic algebra: the equations of the mathematicians. Here was my faith: here I found my dogma of infallibility . . . And now—now—what is left of it? All is caprice: the calculable world has become incalculable.

A person seeking comfort in the deterministic universe may advance the following argument: "The probabilistic nature of the quantum theory is applicable only to the atomic and subatomic world. In the macroscopic-scale phenomena of everyday life, the quantum probabilistic nature is averaged out and has no significant influence. Granting that a chaotic system is unpredictable, I find it governed by deterministic laws. The world is deterministic even though our limitations render it apparently unpredictable."

In response to this, I can show an example of how the probabilistic nature of the quantum theory can influence the outcome of a large-scale phenomenon. Let us consider uranium atoms with atomic mass 238 ($U^{238}$ in chemical notation). A $U^{238}$ atom is unstable and decays by emitting an alpha particle, which is the same as a helium nucleus. Because its radioactive decay is governed by the quantum theory, we cannot predict when it will decay even if we know the quantum state of the atom. We also cannot determine in which direction the alpha particle will be emitted. All directions are equally probable. If there is a chunk of $U^{238}$ atoms weighing a gram, we know that, on average, about three thousand atoms will decay every second. Now suppose that we set up an instrument that generates a surge of electricity whenever an energetic alpha particle enters its opening, and put a minute piece of $U^{238}$ ore in front of the instrument. The instrument is also designed so that a surge of electricity triggers an explosion of a megaton atomic bomb. In theory, it is not technologically difficult to set up such an instrument. If such an instrument were placed in a big city, contrary to social morality, we would not be able to predict when the entire city would be annihilated by an explosion. However, from the area of the opening of the instrument, the distance from the uranium piece to the opening, and the number of $U^{238}$ atoms in the piece, we can calculate the probability that the city would survive until a given time. The survival probability would decrease with time, and the city would be destroyed if we waited long enough. A disaster of such enormous magnitude can be influenced by the quantum effect. This example may seem highly contrived. But highly contrived and structured human activities are ubiquitous. The resources of an entire nation are focused to a specific aim, such as war, by an executive decision. Throughout human history, minor accidental events have had enormous consequences. During the cold war era, both the Soviet Union and the United States were poised for a nuclear holocaust predicated on a single phone call from the leader of either nation.

We do not fully understand how the human brain works. However, we know that it is a nonlinear system which is very sensitive to initial condition. We are also sure that atomic-level activity influences the firing of neurons. Therefore, human decisions, which can have enormous consequences, are influenced by quantum mechanical uncertainty. Not only human beings but also conscious animals are poised to amplify a small input. For example, the shadow of a flying eagle seen by one prairie dog can cause a big commotion in the colony of prairie dogs.

In classical science, a small input results in a small consequence. However, as discovered by modern science, complex systems with chaotic behavior, especially ones with positive-feed back mechanisms, can amplify a small input into a huge outcome. Therefore, the coupling of the probabilistic nature of the quantum theory with the sensitivity to initial conditions of chaotic systems makes chance and randomness an important component in the determination of the course of the world. Long before the advancement of modern science, before determinism challenged the freedom of the world, people knew this, as expressed in *Paradise Lost* by John Milton (1608–74).[8]

> Chaos umpire sits,
> And by decision more embroils the fray,
> By which he reigns; next him high arbiter
> Chance governs all.

Even the Bible, which promotes the concept that a benevolent God closely supervises the world, seems to acknowledge the role of chance.[9]

> I have seen something else under the sun:
> The race is not to the swift
> or the battle to the strong,
> nor does food come to the wise
> or wealth to the brilliant,
> or favor to the learned;
> but time and chance happen to them all.

While some people disliked the unruly world influenced by chance, many hailed the liberation offered by new physics from the tyranny of determinism, as the famous British physicist James Jeans (1877–1946) said:[10]

> The classical physics seemed to bolt and bar the door leading to all freedom of will; the new physics hardly does this; it almost seems to suggest that the door may be unlocked if we could only find the handle. The old physics showed us a universe which looked more like a prison than a dwelling place. The new physics shows us a universe which looks as though it might conceivably form a suitable dwelling place for free man, and not a mere shelter for hima home in which it may at least be possible for us to mould events to our desires and live lives of endeavor and achievement.

The outlook offered by new science is totally different from the mechanistic world view of classical science. In classical science, the actors (material objects), the stage (space and time), and the spectators (objective observers) were separate. In new science, not only the spectator but also the stage participates in the act. In classical science, the actors faithfully followed the pre-written scenario; in new science, there is no pre-written scenarios. In classical science, time simply unfolded the pre-written scenario, as the turning of pages reveals the progress of a pre-written story. In new science, the present is pregnant with many possible futures. Time actualizes one of the possibilities into the reality. The old universe of classical science was a closed-ended universe, but the new universe of modern science is a universe with open-ended possibilities.[11] The old universe was a universe of being (in the sense that no new possibility is introduced with the passage of time), but the new universe is a universe of becoming.[12] In the old universe, human beings were small cogs in a cosmic machine. In the new universe, we human beings can influence our own destiny instead of being controled by a destiny prescribed long before our births. In the new universe, we have freedom to flex our muscles this way or that way. We have freedom to plan and freedom to execute our plans. This point will be discussed further in Chapter 12. The universe is, in a sense, analogous to a seed in the new view, while it was just like a machine in the old view. Although an acorn is encoded to grow up to be a big oak tree, the details of the oak tree—how its branches will fan out, where its roots will grow, and so on—are not predetermined; they are determined as the tree interacts with the environment. Likewise, the details of the universe were not predetermined even though its overall characteristics were predetermined. The universe, however, has no outside environment, unlike an acorn. The universe is self-contained except for God, and parts of the universe form the environment for other parts. The encoding of the universe as a whole is at a much deeper level and much less contrived than the encoding of an acorn. Nevertheless, the universe was encoded to produce life just as an acorn is encoded to produce an oak tree.

In the new universe, not only man but also God is free to interact with the universe. In the old deterministic universe, God could not interact with the universe after the creation, without interrupting the normal operation of the universe as He preordained. In the new universe, God can be immanent (operational within the universe) without being intrusive, as well as transcendental. The differences between the old and new views are summarized in Table 1.

*A New Appreciation of the World*

We have learned that life forms on earth are intimately connected. All living organisms on earth share a common origin, common building blocks, and the same genetic language. The existence of one species depends on the existence of many other species. Even if we find an accessible planet with a climate and an atmosphere perfectly suitable for human habitation, we cannot simply go and live there. The fruits growing on that planet would not be edible to us, however delicious they may look. We would be able to eat neither the vegetables nor the animals living there. We can get nourishment by eating vegetables and animals on earth because we share the same building blocks of life with them. If we were to eat alien animals and vegetables, our enzymes would not be able to digest their proteins and fats (even if their building blocks were similar to our proteins and fats). By the same token, we cannot start a viable vegetable garden in the alien soil simply by planting seeds brought from earth. Plants and vegetables depend on micro-organisms in the soil, and the alien soil would not be expected to contain the right kinds of micro-organism. Furthermore, even if organisms similar to bees and butterflies exist on the alien planet, they may not be attracted to the flowers from earth.

We spent billions of dollars to send people to the moon. To the question whether this money was well spent, one of the frequently given answers is that the windfall technological innovations can justify the expense. Certainly the money was well spent. Without the practical knowledge and technological know-how we gained through the Apollo program, the picture of earth taken from the spacecraft orbiting the moon (Fig. 10.1) alone justifies the expense. Since Copernicus, informed people have known that earth is one of the planets revolving around the sun. However, the picture of the blue earth rising over the lunar horizon made it clear to everyone on earth. To humans bound to the surface of the earth, one half of the vista is earth, the other half the sky. Therefore, in our subconsciousness and in a part of our consciousness, we still have a mental picture of the world composed of an earth floor and a sky ceiling (Fig. 3.2). Through the picture of the earthrise on the lunar horizon, we humans could see the earth from a transcendental position for the first time, and this transcendental view of the earth became a part of our common heritage.

With this picture we began to see the earth as a small globe floating in empty, inhospitable space. The thin atmosphere that shelters us, all the living organisms, looked fragile. After this picture, the word "biosphere" became popular, and the environmental movement got its earnest start. The interconnectedness and interdependence of life on earth and the fragile appearance of the earth's biosphere seen from outside have changed the way we view our world. Not only our scientific understanding of the universe as a whole but space exploration and technology which science has made possible change our world view.

The fact that the existence of life on earth are intimately connected to the characteristics of the universe as a whole evokes religious feeling. So does the immensity and "depth" of the physical world. Since I have already discussed the immensity of the physical world, let us turn to its "depth."[13] The astronomical time scales measured in millions and billions of years are immense. But the "depth" (or compactness) of time is also enormous. To human beings who can blink only a few times per second, one second is a short time, but it is a long time in the domain of subatomic phenomena. Electromagnetic waves of yellow lights, for example, oscillate about five hundred trillion times in one second. Many subatomic particles decay only very small fractions of a second after their creation. For instance, a neutral pion lives on average for about $10^{-16}$ seconds (a ten-quadrillionth of a second).

We can also appreciate the deep layers of material organization. Our bodies are made of many organs such as heart, brain, and lung. These organs are made of tissues that are, in turn, made of cells. Inside each cell are many organic molecules such as DNA, proteins, and enzymes. These molecules are, in turn, made of many atoms of different kinds. Atoms are made of protons, neutrons, and electrons. Now, protons and neutrons have been discovered to be made of three quarks each. This may not be the bottom layer. Some people talk about sub-quarkian particles. It may turn out that the bottom layer is beyond the reach of human beings.

Not only are there many layers of material organization, but new properties also emerge as matter is organized. As water molecules aggregate, the solidity of ice, the liquidity of water, and the gaseousness of water vapor emerge, depending on the pressure and temperature. As matter is organized in more complex manners, life emerges. It is amazing that a small computer chip can perform complex tasks. It is, however, far more amazing that micro-organisms invisible to the naked eye are alive. The information-processing rate of a fly's nervous system is greater than that of a mainframe computer.

Empty space, which was once thought to be simple and empty, has turned out to be neither. Pairs of particles and their antiparticles (an electron and a positron, for example) are created and destroyed continuously in empty space (vacuum). Such processes are called vacuum fluctuations. Although such particles exist for only a tiny fraction of a second before they perish through pair annihilation, they have observable consequences in subatomic phenomena.

The view described above is totally different from the world view of the scientists of the end of the nineteenth century, who believed that the world was made of billiard-ball-like atoms interacting with each other in passive empty space via electromagnetic and gravitational forces. While the physical reality portrayed by classical physics was relatively shallow, the physical reality portrayed by modern physics is deep, and evokes in us a sense of mystery and awe. While classical physicists thought that they may have reached the bottom layer, modern physicists realize that it may be far from them and perhaps beyond their reach. The sense of mystery and awe evoked by the modern world view is tantamount to religious feeling for most people who take the time to conceptualize it.

## Notes and References

1. Wheeler, J. A., "Foreword" in J. D. Barrow and F. J. Tipler. *The Anthropic Cosmic Principle*. New York: Oxford University Press, 1986. The word "man" here means the human race. It is a peculiarity of English that the word "man" meaning a male person is used to represent the human race. For example, in East Asian languages, there are separate words for a human and a male person, and the word for a male person is not used in place of the word for a human being. The word for God is also gender neutral in East Asian languages.

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Table 1: The World Views of Classical and Mordern Physics

| Category | Classical Physics | Modern Physics |
|---|---|---|
| Objective observation | Possible | Impossible for atomic & subatomic phenomena |
| Prediction | Deterministic<br>(Exact prediction) | Probabilistic (Impossible for chaotic systems)<br>(No exact prediction) |
| Nature of time | Reversible<br>Non-directional | Irreversible<br>Directional |
| Chain of causality | Unique | Multiple paths; complex |
| Possibility | Closed possibility | Open possibility (Potentiality → Actuality) |
| Descriptive words | Deterministic;<br>Universe of being | Emergent; Inventive;<br>Universe of becoming |
| Analogy | Machine | Seed |
| Human free will | Possible in dualism[a] | Possible |
| Creation[b] | One-time creation | Continuous creation |
| God's relation to the universe[b] | Transcendental | Transcendental and Immanent |

[a] Humans can have free will in Descartes's dualism, because the mind does not obey deterministic mechanical laws in this view. This will be discussed further in Chapter 12.

[b] These items are not areas of science but are related to the scientific world view. They are discussed further in Chapters 14 and 15.