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Complete List of Authors	■ Dr Man Ho Chan

God and the initial conditions

Man Ho Chan

Department of Physics, The Chinese University of Hong Kong

Department of Religion and Philosophy, Hong Kong Baptist University

Abstract

It is commonly believed that the physical laws in our universe are fine-tuned for evolution of life. In this article, I show that the initial conditions on Earth are also fine-tuned. It is very unlikely for these conditions to be generated randomly through natural processes. It may suggest that our Earth is designed by God for the sake of life creation and evolution.

Introduction

Recent scientific investigations indicate that there are many important fine-tuned constants in the nature for life to evolve. Many of these constants are related to the fundamental constants of forces (electromagnetic, gravitational, weak and strong forces) (Rees 2000). Nevertheless, these constants are not the only way to govern the consequences. All subsequent motions of particles are governed by two subjects: physical laws and initial conditions. Basically, given some required initial conditions, physical laws can let you know all the subsequent motions. For example, in Newtonian mechanics, the motions are mainly governed by the Newton's second laws, which is a second order differential equation:

$$F = m\frac{d^2x}{d^2t} \tag{1}$$

where F, m, x, t are the force on the particle, mass of the particle, displacement function (position) and time respectively. Theorem in differential equation states that at least two initial conditions should be given to a second order differential equation so that a subsequent motion can be well defined. Usually, given the initial position and velocity of a particle, the future trajectory of the particle can be derived. Therefore, initial conditions are very important in knowing the particle behaviors. For example, in the evolution of our universe, the primordial fluctuation Q, matter-energy content in the universe Ω and the cosmological constant λ can be regarded as the initial conditions. Given all these numbers, we can predict the evolution of our universe according to Friedmann equations. However, in very small scales, the behavior of a particle becomes indeterministic and quantum mechanics is needed to account for the motion. In the following, we will only focus on the large scale objects such that there would be no quantum mechanical effect.

Life is highly dependent on the environmental changes. Our Earth is not habitable if the surface temperature of the Earth is a few Celsius degrees higher. All the environment changes are governed by physical laws and initial conditions. A slight change in the initial conditions and physical laws may give rise to a drastic change in the environment so that life cannot live anymore. For example, Venus is a similar planet to Earth. Its temperature, however, is about 400℃ due to severe greenhouse effect.

Obviously, no life known can be living in such environment. In addition, evolution of life also sensitively depends on the environmental changes. For example, mammals become a dominant force in nature because the fall of dinosaurs due to drastic change in environment. The evolution series would be greatly altered if there were no such environmental changes in the past (Scheffer 2009, 172). Therefore, initial condition is a very important parameter that should be considered in life evolution.

In this article, we briefly describe how the initial conditions were set and made changes in the environment. It is not necessary to trace back all the conditions back to the beginning of our universe, even though they actually affect the initial conditions of the Earth. Here we mainly examine whether fine-tuning exists in the initial conditions at the beginning of the Earth. In the following, by using the fact that initial conditions can sensitively affect the environment, I show that the initial conditions on Earth is highly fine-tuned after its formation. That is to say, Earth is very likely designed by God for the sake of life evolution.

Initial conditions and the environmental changes

Environmental changes and climatic changes are inter-related. All climatic changes are governed by atmospheric science, which is composed by some physical and chemical laws (e.g. Navier-Stokes Equation). Theoretically, given all the initial conditions and scientific laws, all climatic changes can be predicted. However, this is not the actual case. We noticed that weather forecasting is not always precise. For example, no one can precisely predict any typhoons would be created after one month or the future path of a typhoon. The reason behind is that the physical laws (or the equations) that govern the climatic changes are highly non-linear. Basically, non-linear physics is hardly predictable. Mathematically, the solutions of the non-linear equations are sensitively dependent on initial conditions. Errors would be accumulated and grow with time. Even a very tiny difference in the initial condition would generate a great difference in the result. For example, the “butterfly effect” – a movement of butterfly’s wing may result in a storm in another continent - is one of the famous effects that related to the non-linear physics.

In atmospheric science, we need several initial conditions to specify the climatic change. These conditions include temperature, pressure, density of air, chemical composition of air, velocity of air, energy supply from Sun and water content in air (Salby 2012). All these parameters are correlated to each other. In the following, I will briefly review how these conditions should be fine-tuned for life.

Composition of Earth

Our Earth can be roughly divided into two parts: “air” and “ground (including sea)”. For the ground, we have 92 naturally found elements, in which 25 are presently considered essential for life (Denton 1998, 74). No complex life would exist if any one of them is missing. Some of these elements (carbon, oxygen) are generated from stars’ nuclear fusion; and the remaining elements (cobalt, copper) are generated from supernovae. Therefore, only a right amount of explosion from supernovae may result in this specific composition. However, some elements that are not directly essential for life (no role in metabolic reactions) are also crucial for life. They are radioactive elements. In general, radioactive elements are harmful to life because they would emit high energy radiation which can cause cancers. Surprisingly, recent studies show that a considerable amount of radioactive elements are essential to generate life. They provide heat by radioactive decay which can warm the interior of Earth shortly after its formation. This effect causes differentiation of elements in Earth which is important in life evolution because the elements that crucial for life can rise to an upper region to increase the probability of generating life. Also, the differentiation process can cause some radioactive elements floated to the surface in order to prevent overheating of the Earth’s core. These processes are sensitively dependent on the amount of the radioactive elements. Too much radioactive elements would melt the Earth while no differentiation would be happened if there were too few radioactive elements (Denton 1998, 81-83).

Moreover, the presence of radioactive elements helps the movement of Plate Tectonics (Denton 1998, 83-84). The Plate Tectonic movement recycled carbonate and silicate rock through the planet’s interior, which can also stabilize the atmosphere over geologic time. If there were no movement of Plate Tectonic, no life would be evolved. The mass of a planet that can undergo plate tectonics should be within 0.5-10 Earth masses (Haghighipour 2008).

Besides, our atmosphere is also fine-tuned for life. The atmospheric pressure of Earth in the past was ranging from 500 mmHg – 1000 mmHg, which is quite stable in history. If it were 10 times smaller, body fluids would vaporize at $38°C$. If it were 10 times smaller, the respiration would be prohibitive (Denton 1998, 128). Therefore, the atmospheric pressure in Earth is fine-tuned. Moreover, one of the most important gases in the air, oxygen, also has some fine-tuned properties. Oxygen provides ozone (O_3), which can prevent harmful ultraviolet radiation to reach the Earth. Also, the oxygen content level (about 21% now) is at point where risk and benefit nicely balance. If there were too much oxygen (above 25%), very little land vegetation could survive. The probability of a forest fire being ignited by lightning increases by as much as 70 percent for every 1 percent increase in the oxygen level (Denton 1998, 121). If there were too little oxygen, not enough energy would be generated for complex life and the diversity of life would be largely decreased. In fact, the oxygen content and atmospheric pressure are controlled by a complex set of feedback mechanisms involving complex interactions between the hydrosphere, biosphere and the material making up the crust of Earth (Denton 1998, 129). The interactions between different cycles in different spheres are related to chemical properties of different molecules. Besides these fine-tuned cycles, one of the major fine-tuned values is the mass of Earth. As mentioned above, the mass of Earth controls the plate tectonics. It also controls the oxygen content and the atmospheric pressure. A few percent changes in the mass of Earth may result in a drastic change in the oxygen content and the atmospheric pressure. Therefore, Earth should not be too large or too small.

Maintenance of constant content

In most metabolisms, oxygen is consumed and carbon dioxide is released. Therefore, one can imagine that oxygen content is decreasing and carbon dioxide content is increasing. If so, after a long history, lacking of oxygen and greenhouse effect would become more serious which make life impossible. Fortunately, it is not the case because some cycles help to balance the content of essential chemicals over the past 4 billion years!

There are many essential cycles to life, such as carbon cycle, oxygen cycle, nitrogen cycle, phosphorous cycle, sulfur cycle, calcium cycle, iron cycle and sodium cycle. Most of the cycles are interdependent (Denton 1998, 88-89). Breaking down of any cycles may result in significant changes in other cycles, which would make life impossible. Technically speaking, these cycles are "highly non-linear". Moreover, these cycles also depend on temperature, tectonic cycle, etc. These cycles would generate new essential chemicals by some feedback mechanisms or chemical processes when these chemicals were consumed by organisms. For example, the content of carbon dioxide is regulated by a negative feedback system via the weathering of silicate rocks. The silicate rocks would increase the uptake rate of the carbon dioxide if the carbon dioxide content is increased. This helps to stabilize the carbon dioxide content and the temperature of the Earth (Denton 1998, 90).

Interestingly, cycles stabilize the chemical content in Earth, but also allow some variations, which are not fatal to life. I call it "globally stable but locally fluctuate". These fluctuations and variations do not overwhelm the overall stability, but provide enough forces to generate diversity. Without these variations, no diversity would be produced and evolution might not be possible (because food chains cannot be set up). However, too much variation would make the content unstable for life. Therefore, these cycles, which mean the fundamental constants and initial conditions involved, are fine-tuned. Interestingly, the "globally stable but locally fluctuate" phenomenon appears in many different circumstances. For example, the evolution of our universe is globally stable (very homogeneous and isotropic) but some fluctuations exist (the primordial fluctuation is not zero, but a very small number). Without this fluctuation, no galaxies or stars would be evolved. If the fluctuation is too large, all galaxies or stars would become black holes.

Origin of life

In the 19th century, Scientist Louis Pasteur showed that if a broth or solution was properly sterilized and excluded from contact with micro-organisms, it would remain sterile indefinitely. This experiment disproved that life could be generated spontaneously (Conway 2003, 1). If it were the case, how did the first life come from? In the bottom-up scenario, the first life is evolved from some simple molecules by natural processes. It is known as the chemical evolution. According to this scenario, all major building blocks of life such as protein, RNA, DNA were formed from more basic chemicals by chemical reactions.

A collection of these basic chemicals is called the prebiotic soup. These chemicals include water, lipids, sugars, amino acids, phosphate and nitrogenous bases. Besides natural processes, some believe that the first life could be made by some other intelligent life or supernatural being. Here, I mainly follow the bottom-up scenario and discuss the probability of getting the first life naturally.

Prebiotic soup

It is commonly believed that only simple molecules (e.g. water, oxides) were formed when the formation of Earth was just complete. More complex molecules such as amino acids and phosphate need to be generated from chemical processes. In the early 1950s, Stanley Miller generated some important complex molecules that are essential for life by experiment. He used a flask of water to represent the primordial ocean and another flask containing water vapour, methane, ammonia and hydrogen to represent the primordial atmosphere. By using a continuous electrical discharge that represents lightning, the gases interact and reaction products would be formed. One week later, he found that amino acids were formed after the experiment (Conway 2003, 19). However, recent geochemical evidence shows that the primordial atmosphere should contain carbon dioxide, nitrogen, water vapour and oxygen, but not the gases that used in the Miller's experiment (Meyer 2009, 224). Models of atmospheric evolution indicate that a methane- and ammonia-rich reducing atmosphere would be easily destroyed by sunlight. Therefore, the synthesis that proposed by Miller is highly improbable. Even if the experimental result is right, many amino acids that generated (e.g. pipecolic acid) from the experiment didn't found in protein on Earth (Conway 2003, 21). Now, many scientists believe that the prebiotic soup could not be generated from the primordial atmosphere through chemical processes because of extremely low probability.

Another theory states that the prebiotic soup is mainly generated from extra-terrestrial objects. In 1969, a town called Murchison in Australia was shattered by a carbon-rich meteorite (Conway 2003, 20). Scientists discovered that this meteorite contained organic molecules including amino acids, lipids, monosaccharides, phosphate and nitrogenous bases (Conway 2003, 23). It indicates that the early Solar System must have been a place in which organic chemistry was taking place. However, there are still some essential organic molecules for life that could not be found in the Murchison meteorite, such as polysaccharides, proteins, nucleic acids (Conway 2003, 23). These large organic molecules might be polymerized by some mechanisms that would achieve the properties of life. By using statistics, we can estimate the minimum time to accumulate enough organic materials for life. The total accumulated carbon content is given by

$$x_c = \sum_i P_i a_i m_i t \qquad (2)$$

where P_i, a_i, m_i are the impact probability, carbon content ratio, mass of particular meteorite i respectively, and t is the estimated time. The value of a_i is well known, and the values of P_i and m_i can be obtained from statistics based on our records. The mass of carbon in the biosphere is about 6×10^{14}

kg and the estimated $\sum_i P_i a_i m_i$ is 0.32×10^6 kg (Conway 2003, 24 and 304). Therefore, the required time is about 1.9 billion years, which is quite closed to the first life appeared since the Earth formed (about 1 billion year). Many scientists start to believe that the prebiotic soup or life may come from the extra-terrestrial objects. In the above calculation, we can notice that the probability P_i is an empirical and a fine-tuned value. If P_i is ten times smaller, the required time t for carbon accumulation would be 19 billion years, which is impossible for life because Sun is already dead. If P_i is ten times larger, our Earth would be too easy for impact from meteorites, which is fatal for most complex life. This fine-tuned P_i mainly depends on the size and the relative gravitational strength of Earth. Moreover, the initial conditions of our Solar System have to be fine-tuned. For example, the location of the meteorites should not be too close to or too far away from Earth. Otherwise the impact probability would be either much higher or smaller. Also, the mass of the meteorites should not be too large or too small. Otherwise, either extinction of life would be happened or no life would be created.

To conclude, in order to generate the prebiotic soup, some fine-tuned initial conditions are required.

Macro-organic molecules

Scientists believe that the macro-organic molecules, such as protein, RNA, DNA, etc. could be formed from the prebiotic soup. However, the actual mechanisms are very poorly understood. It is because some specified structures make these molecules difficult to be produced naturally. Here, we use protein as an example for discussion.

Proteins are polymerized amino acids. A very small protein can contain about 150 amino acids, which has 10^{195} possible sequence combinations (Meyer 2009, 205). In general, not all the amino acids can form chains by chemical bonds to become protein molecules. Only for those amino acids that can form a peptide bond would fold into a protein. When amino acid mixtures are allowed to react in a test tube, the probability of getting peptide bonds is about ½. In other words, for simple protein that contains 150 amino acids, the probability of getting this protein by random is $(1/2)^{149} = 10^{-45}$, which is very low (Meyer 2009, 206).

Moreover, molecules with identical chemical formulae may have different structural arrangements. For example, in amino acids, there are two different forms, left-handed and right-handed. This chemical property is called chirality (Conway 2003, 24). Out of 20 amino acids used in forming protein, 19 can exist as left-handed and right-handed forms. In the absence of life, the chemical reactions from amino acids generally create equal numbers of left- and right-handed forms. However, what is remarkable is that all life on Earth uses only the left-handed forms of amino acids for producing proteins. Therefore, the probability of creating a protein with 150 amino acids randomly is $(1/2)^{150} = 10^{-195}$. Combined with the probability of forming peptide chain, the total probability of creating a protein with 150 amino acids randomly is 10^{-240}. This is an extremely small probability. If this protein has to be created randomly from nature, some fine-tuned conditions must be satisfied. Nevertheless, many practical proteins for life need more than 150 amino acids, and the required fine-tuning is much more serious.

One possible mechanism for generating left-handed amino acids in nature has been postulated. The amino acids that found from meteorites show an excess of the left-handed amino acids. One possibility is that the excess left-handed amino acids are formed by the ultraviolet circularly polarized light (UVCPL). The electric field direction rotates along the beam which destroys one form of the molecules (right-handed) more readily than the other form (left-handed) (Conway 2003, 27). These UVCPL might come from the star-forming regions in space. If this is true, the total probability of generating a protein molecule naturally may increase significantly. However, there should be a fine-tuned condition such that the UVCPL is pointing to our Solar system, and these radiations should have enough intensity to increase the amount of left-handed amino acids. Therefore, the mechanism that can generate excess left-handed amino acids also requires fine-tuning. In any case, the probability of getting a protein is still very low.

Discussion

The origin of life is a mystery. Two possible scenarios of creating prebiotic soup – chemical evolution and accumulation from extra-terrestrial objects – require fine-tuned conditions, such as suitable size of Earth, chemical composition, probability of meteorite impact and initial conditions of Solar system. Even if the prebiotic soup could be generated naturally, it is necessary for them to evolve into some larger molecules such as amino acids and proteins. This requires some correct orientation for our Solar system to receive UVCPL. Moreover, suitable temperature, environment and atmospheric composition are necessary for life to evolve. All these require some fine-tuned initial conditions on Earth. The existence of such fine-tuned conditions may suggest that the evolution of life is designed by God. Otherwise, it is very unlikely to generate so many fine-tuned initial conditions randomly by natural processes. Therefore, not only the fine-tuning fundamental constants in our universe, the fine-tuned initial conditions on Earth also suggest God exists in the nature.

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