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## **The Dance of the Fertile Universe**

### **Introduction**

Did we come about by chance or by necessity in the evolving universe? The first thing to be said is that the problem is not formulated correctly. It is not just a question of chance or necessity because, first of all, it is both. Furthermore, there is a third element here that is very important. It is what we might call the “fertility” of the universe. This is the dance of the fertile universe, a ballet with three ballerinas: chance, necessity and fertility. What this means is that the universe is so fertile in offering the opportunity for the success of both chance and necessary processes that such a character of the universe must be included in the search for our origins in the universe. In this light I am going to try to present in broad strokes what I think is some of the best of our modern scientific understanding of the universe, and then I will ask the question at the end: What does this say about the God who loves us and who made this universe?

### **The Universe of Modern Science**

The universe is 13.7 billion years old and it contains about 100 billion galaxies each of which contains on the average 200 billion stars of an immense variety. Since the Big Bang, 13.7 billion years ago, the universe has been expanding. Figure 1 shows one slice of that universe.

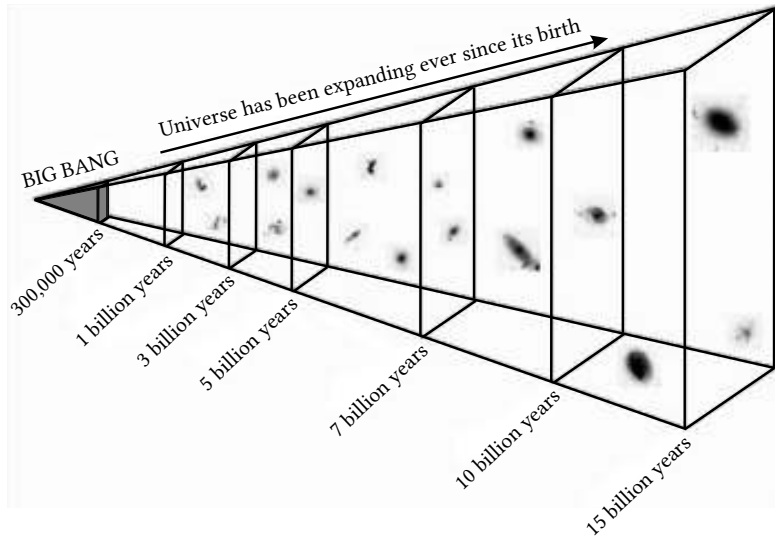


Fig. 1. From the Big Bang to now.

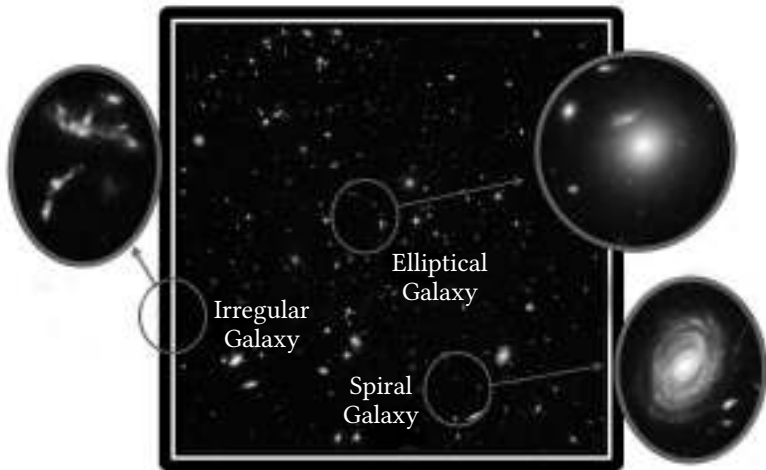


Fig. 2. Hubble Ultra Deep Field.

We are at 13.7 billion light years distant from the Big Bang and with large telescopes we look back as far as we can. Note that the more distant we look in the universe the further back in time we are looking. So, when we look back 12 billion years we are seeing the young universe (Fig. 2). Except for a very few dots which are nearby stars of light these are all galaxies. This photograph is a very small piece of the total sky. By a statistical estimate we arrive at the count of about 100 billion galaxies in the universe and a total of about 20,000 billion billion stars.

The Andromeda galaxy (Fig. 3), our sister galaxy, is a typical spiral galaxy.



Fig. 3. The Andromeda Galaxy.

It contains about 200 billion stars and measures 100,000 light years across. Figure 4 shows an edge-on sketch of our galaxy, the Milky Way, which is very similar to the Andromeda galaxy.

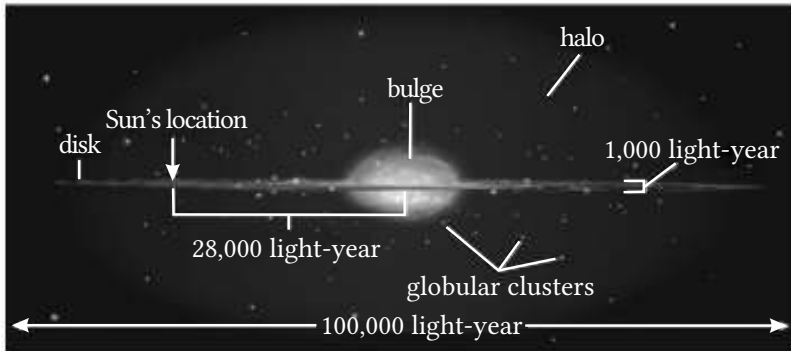


Fig. 4. The Milky Way Galaxy.

It is a very flattened system, 100 times longer than it is thick. The Sun is about two-thirds of the way out from the center of the galaxy.

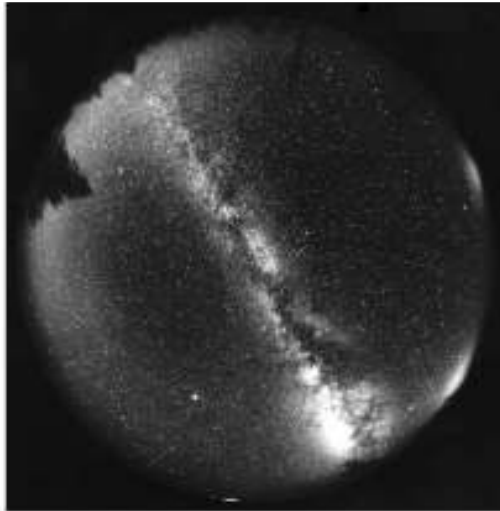


Fig. 5. Flattened disk of the Milky Way Galaxy.

In Figure 5 we see a photograph of the flattened disk of our galaxy taken at the Mt. Graham International Observatory in Arizona, USA

where the Vatican Advanced Technology Telescope is located and in Figure 6 we have a small section of this disk in optical light. We note that there are many dark clouds along this disk. These dark clouds are where stars are being born.



Fig. 6. Small section of flattened disk of the Milky Way Galaxy.

How are stars born? If we look in infrared light at the center of the Orion Nebula we see boiling gas and dust (Fig. 7).

If we look even closer up with the Hubble Space Telescope (Fig. 8) we see the fine separation of blue gas and red gas in the midst of a rather chaotic structure. The fact is that stars are being born in this gas. And where the hottest, most massive and, therefore, brightest stars are already born, they are irradiating the gas, and it is giving off hydrogen alpha radiation, which is red light. In this way we can identify star birth regions.

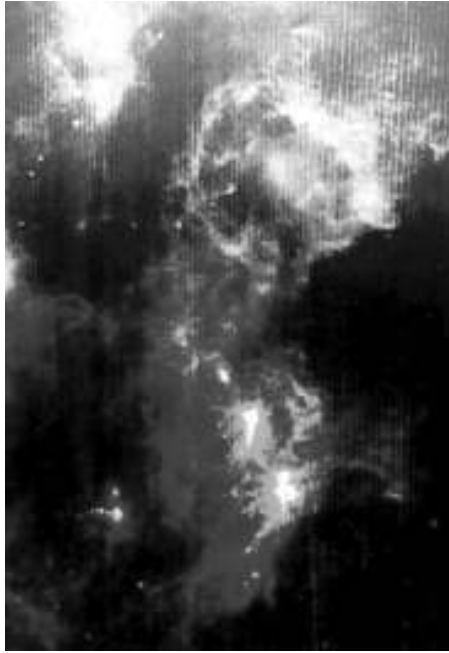


Fig. 7. The center of the Orion Nebula in infrared light.

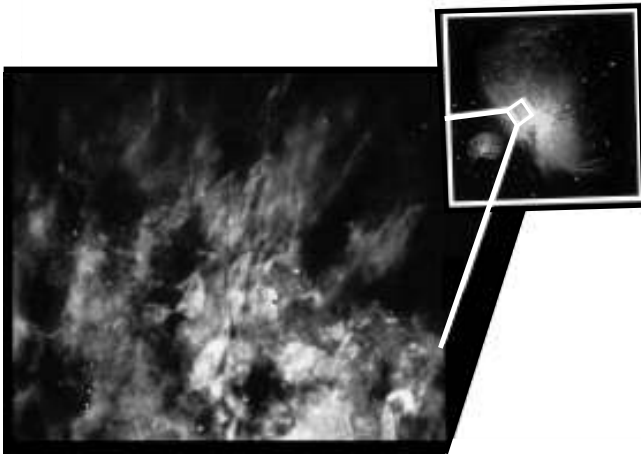


Fig. 8. The fine separation of blue gas and red gas in the center of the Orion Nebula.

How is a star born? It happens by the normal laws of physics. A cloud of gas and dust, containing about 100 to 1,000 times the mass of our sun, gets shocked by a supernova explosion or something similar and this causes an interaction between the magnetic and gravity fields. The cloud begins to break up (Fig. 9) and pieces of the cloud begin to collapse.



Fig. 9. Break up of clouds and collapse of pieces.

As any gas collapses, it begins to heat up; as it expands, it cools down. In this case the mass is so great that the internal temperature reaches millions of degrees and thus turns on a thermonuclear furnace. A star is born. A thermonuclear furnace can only occur by having a cloud collapse and raise the temperature. This can only occur, therefore, in stars, with one exception, namely, in the very hot early universe before galaxies or stars were born, when for a brief time the universe was at a very high temperature.

Stars also die. A star at the end of its life can no longer sustain a thermonuclear furnace and so it can no longer resist against gravity. It collapses for a final time, explodes and expels its outer atmosphere

to the universe. This may happen peacefully (Fig. 10) or it may happen in a violent cataclysmic explosion, called a supernova.

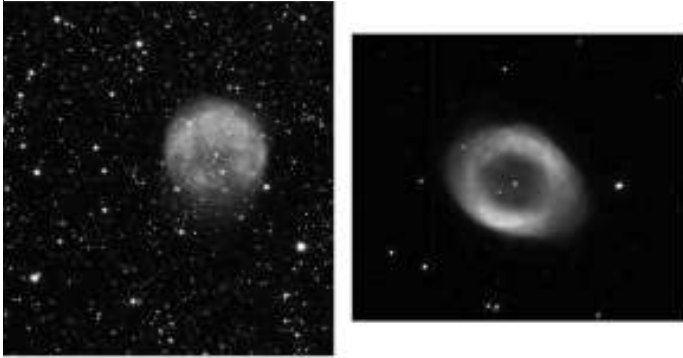


Fig. 10. A peaceful death of stars.

The most famous of these is the Crab Nebula which has a pulsar at the middle as its dead star (Fig 11).



Fig. 11. The Crab Nebula with a pulsar at the middle as its dead star.



So stars are born and stars die. And as they die they spew left over star matter out to the universe (Fig. 12).

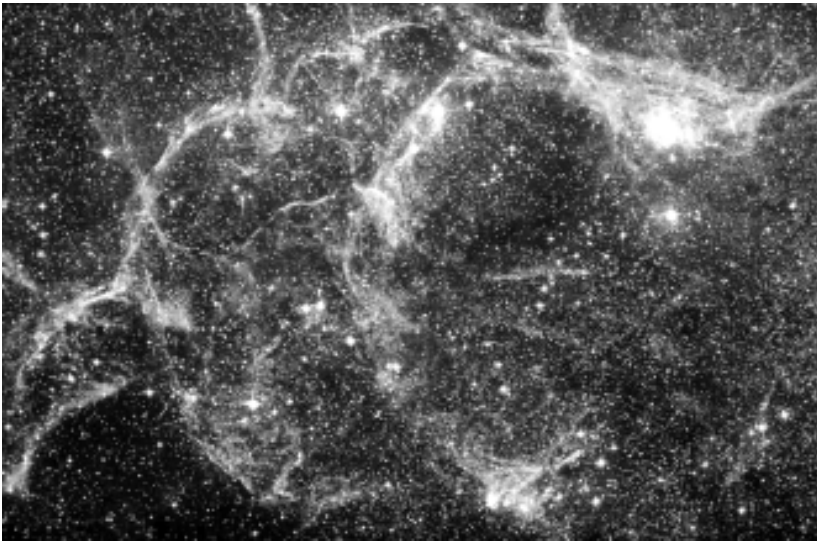


Fig. 12. The Veil Nebula.

From this gas of a supernova remnant another generation of stars will be born. The birth and death of stars is very important. If it were not happening, you and I would not be here. In order to get the chemical elements to make the human body, we had to have three generations of stars. A succeeding generation of stars is born out of the material that is spewed out by a previous generation. But now notice that the second generation of stars is born out of material that was made in a thermonuclear furnace. The star lived by converting hydrogen to helium, helium to carbon, and if it were massive enough, carbon to oxygen, to nitrogen, all the way up to iron. As a star lives, it converts the lighter elements into the heavier elements. That is the only way to get carbon and silicon and the other elements to make life. To get the chemistry for life we had to have the stars regurgitating material to the universe.

Obviously this story of star birth and death is very important for us. Out of this whole process around one star, which we call the sun,

a group of planets came to be (Fig. 13) and among them the little grain of sand we call the Earth (Fig. 14).

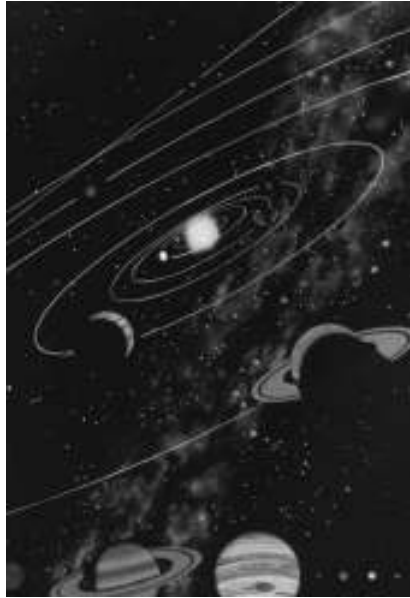


Fig. 13. Solar planetary system.



Fig. 14. Our Earth.

An amazing thing happened on that little grain of sand. We know it happened and we deal with it every day, but we do not reflect sufficiently about the amazing occurrence in the 16th and 17th Centuries with the birth of modern science. We developed the capacity to put the universe in our heads (Fig. 15). We do that by using mathematics, physics, chemistry and biology.

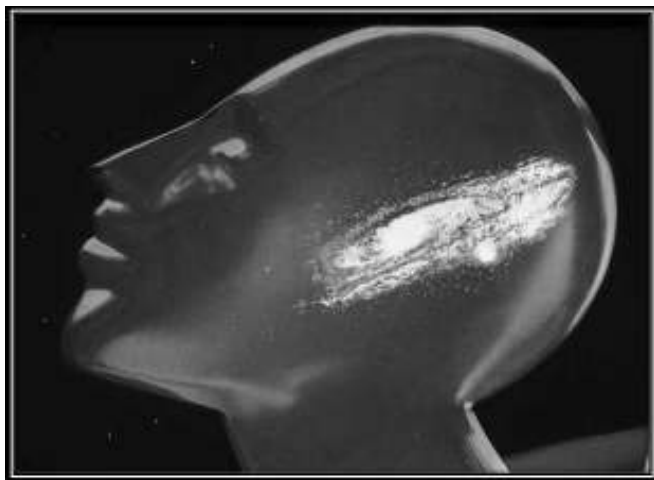


Fig. 15. We can put the Universe in our heads.

Since we developed the capacity to put the universe in our heads, many questions come to us. For instance, how did we humans come to be in this evolving universe? Let us first review what we know of the history of the expanding universe (Fig. 16).

As it aged, distances got larger in the universe and certain key events took place. Quarks combined to form elementary particles, which in turn formed atoms and then molecules. The universe became transparent and the cosmic background radiation came to be. Galaxies and stars were formed. The first microscopic life forms came to be after twelve billion years in a 13.7 billion year old universe. Why did it take so long to make primitive life? We have already discussed one reason. We did not have the chemistry to make life until we had had three generations of stars.

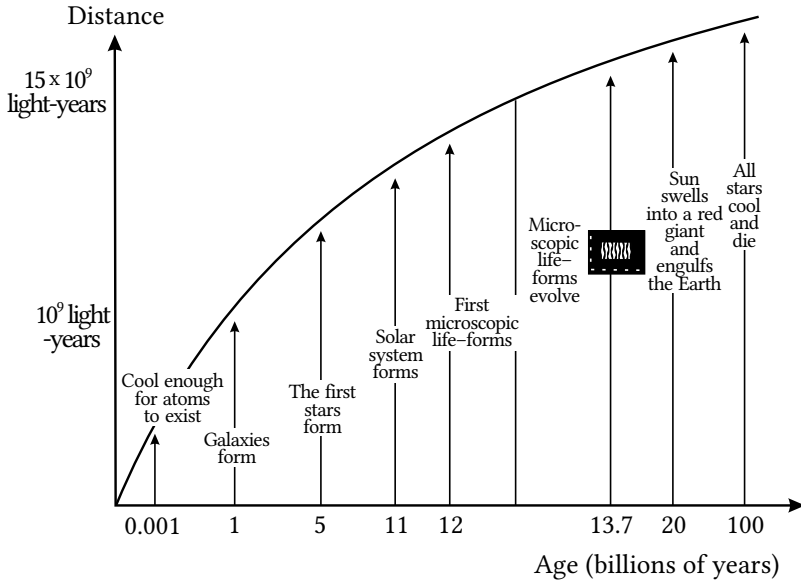


Fig. 16. Outline of the history of the Universe.

Before proceeding let us look in a different way at the aging of the universe by scaling down to make the universe one earth day old (Figs. 17).

Suppose we make the 13.7 billion year old universe have the age of one earth year; then:

- |  |  |
|--|--|
| 1 January: <i>The Big Bang</i>                     | 31 December:                               |
| 7 February: <i>The Milky Way is born</i>           | at 7:00:00 pm: <i>First hominids</i>       |
| <u>14 August: <i>The Earth is born</i></u>         | <u>at 11:58:00 pm: <i>First humans</i></u> |
| <u>4 September: <i>First life on the Earth</i></u> | at 11:59:30 pm: <i>Age of Agriculture</i>  |
| 15 December: <i>The Cambrian Explosion</i>         | 47 pm: <i>The pyramids</i>                 |
| 25 December: <i>The dinosaurs appear</i>           | <u>58 pm: <i>Jesus Christ is born</i></u>  |
| 30 December: <i>Extinction of the dinosaurs</i>    | <u>59 pm: <i>Galileo is born</i></u>       |
|  | at 12 midnight: <i>today</i>               |

Fig. 17. A calendar of the evolving Universe.

I have underlined certain key events which might set the stage for asking the question: How did we humans come to be in this evolving universe? We came to be two minutes before the end of the year!!!

### Life in the Universe

It is of some interest to note that, if we take all kinds of objects in the universe from the proton on up to the visible universe itself, and measure two of the simplest things one can measure: size and mass, we find quite an amazing correlation (Fig. 18).

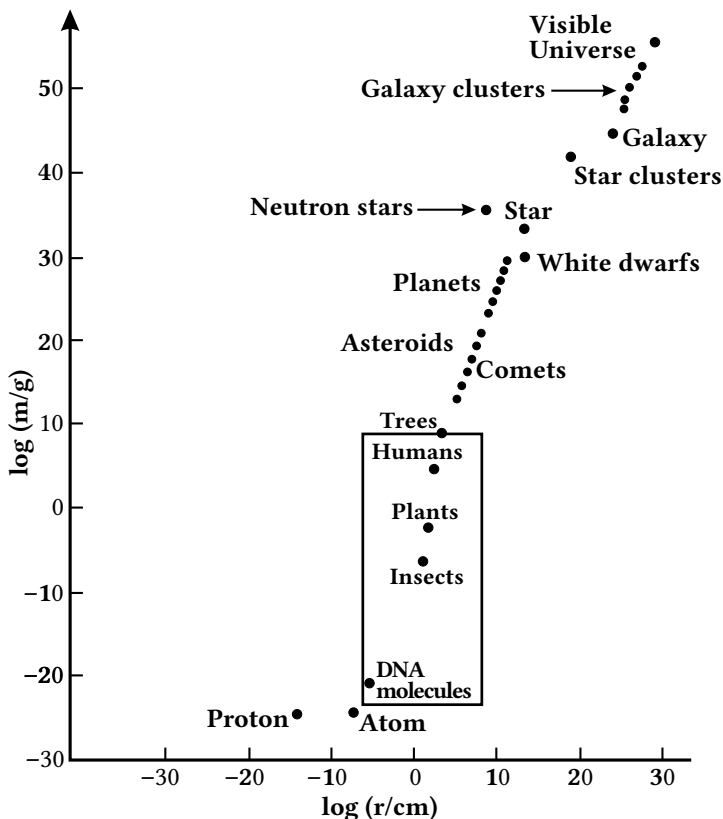


Fig. 18. The size and mass relationship in the Universe.

Atoms, trees, birds, humans, galaxies, the visible universe itself, all fit the same relationship. There may be many hidden reasons for this correlation, but it surely should make us curious as to whether we, together with all other beings, came out of the evolving universe.

It is quite clear that we do not know everything about the process of biological evolution. But it would be scientifically irresponsible to deny that through neo-Darwinian evolution the human brain is a result of a process of chemical complexification in an evolving universe (Fig. 19).

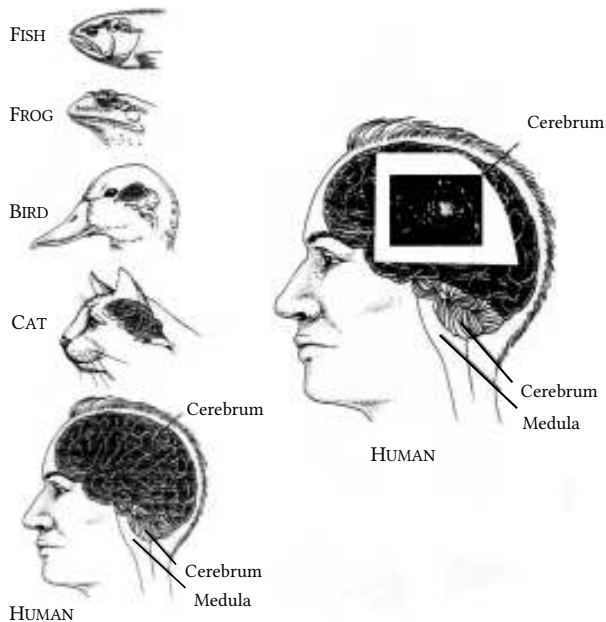
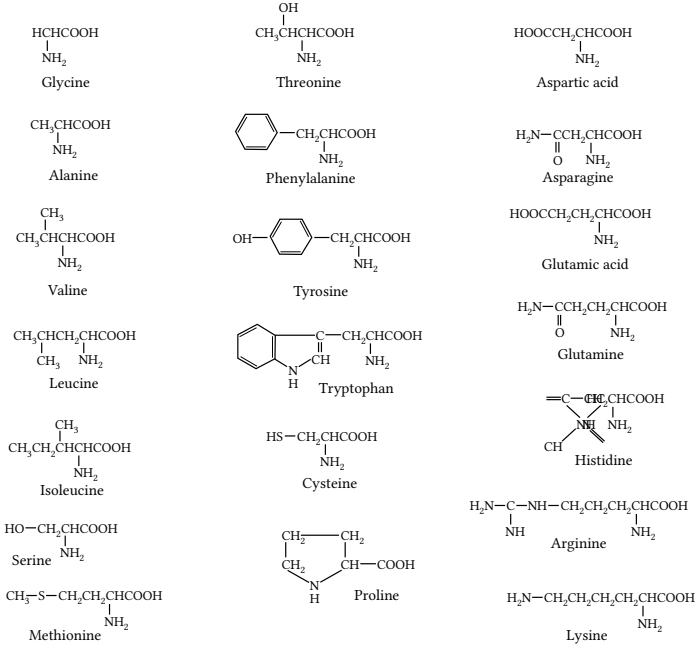


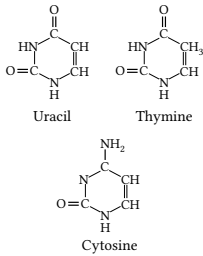
Fig. 19. Through neo-Darwinian evolution the human brain is a result of a process of chemical complexification in an evolving Universe.

After the universe became rich in certain basic chemicals through three generations of stars, those chemicals got together in successive steps (Fig. 20) to make ever more complex molecules.

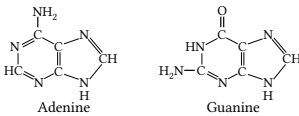
The amino acids (in un-ionized form)



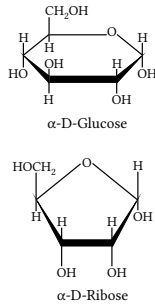
The pyrimidines



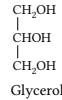
The purines



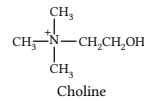
The sugars



A sugar alcohol



A nitrogenous alcohol



A fatty acid

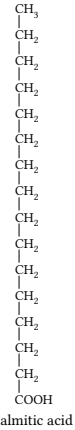


Fig. 20. Some molecules important to life.

Finally in some extraordinary chemical process the human brain came to be, the most complicated machine that we know.

Let us now return to the question asked at the beginning. Did we come about by chance or by necessity in the evolving universe? From the best of modern science I respond by describing the dance of the fertile universe. For 13.7 billion years the universe has been dancing a fertile ballet. One of the ballerinas is chance. When we speak about chance we mean that it is not certain that a given event would happen. The “uncertainty” can be calculated in mathematical terms. Such a calculation takes into account how big the universe is, how many stars there are, how many stars would have developed planets, etc. In other words, it is not just guesswork. There is a foundation in fact for making each successive calculation.

A good example of a chance event would be two very simple molecules wandering about in the universe. They happen to meet one another and, when they do, they are destined to make a more complex molecule because that is the nature of these molecules. But the temperature and pressure conditions are such that the chemical bonding to make a more complex molecule cannot happen. So they wander off, but they or identical molecules meet billions and billions of times, trillions if you wish, in this universe, and finally they meet and the temperature and pressure conditions are correct. This could happen more easily around certain types of stars than other types of stars, so you can consider all kinds of other factors. The point is that from a strictly mathematical analysis of this, called the mathematics of nonlinear dynamics, one can say that as this process goes on and more complex molecules develop, there is more and more direction to the process. As the complexity increases, the future complexity becomes more and more predetermined.

All of this is happening in a universe that is so fertile that the eventual outcome has a kind of predetermined nature. This predetermined nature may be represented by a tree, the Tree of the Universe (Fig. 21a). Everything that ever happened in the universe, from the making of quarks to the making of toenails, is all here. Even those processes that never succeeded, that failed, every dead leaf and dead



branch has been conserved. Every meeting of molecules in inopportune circumstances is here. The tree has never been pruned.

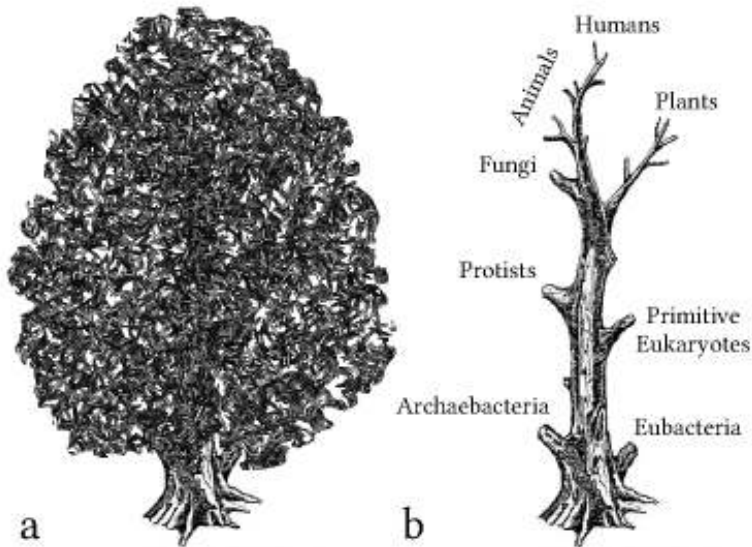


Fig. 21. The Tree of the Universe with certain branching to various forms of life.

But blow a quiet breeze through this tree and what will you see? You will inevitably see something that resembles the bare trunk of a tree with certain branching to various forms of life and ending at the top with the human being (Fig. 21b). The result is inevitable because with a combination of chance and necessary processes in a very fertile universe with so many opportunities there is a narrowing down of the evolutionary process due to the nature of physics, chemistry, biology and nonlinear dynamics. Of course, I have simplified the tree. For biological systems it is really a bush (Fig. 22). If we truly accept that there are chance processes involved, then the branching of the tree could be somewhat different. But since complexity proceeds towards an ever more determined direction the trunk of the tree could not be

very different. The paleontology, biology and chemistry behind all of this are quite uncertain, but it is clear that something like this would happen.

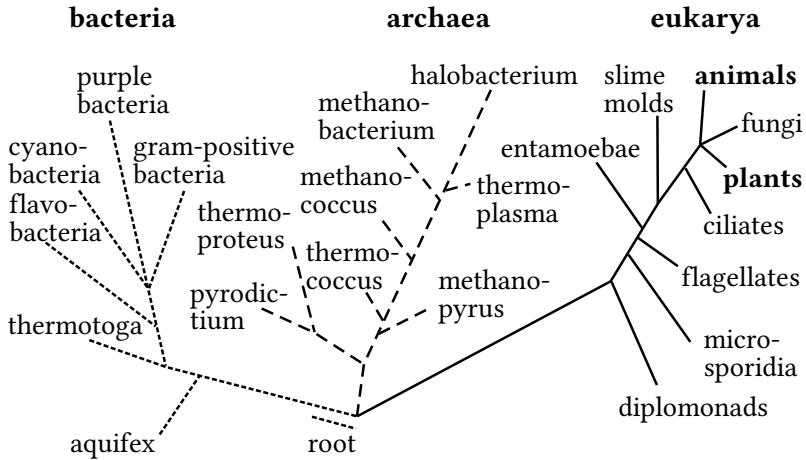


Fig. 22. A bush of the biological systems.

### The God Question

Do we need God to explain this? Is there a kind of finality, directedness, purpose behind this? When science detects such directedness in the evolution of life in the universe, it inevitably leads us to talk about purpose in some fashion. The fear among scientists is that in talking about purpose we are inevitably going to bring God into the picture. That is not true. We do not need God to explain the universe as modern science sees it today. But once I believe in God, the universe as science sees it today says a great deal about that God in whom I believe. Science seeks natural explanations for natural events and is, therefore, completely neutral with respect to the existence or not of God.

That having been said, then several approaches can be taken in the Science-Religion dialogue. Here is one approach that I would like to

share with you. I truly believe that God is a person and revealed himself personally to us, to his chosen people and by means of his chosen people to all of us. He did that in history, in Church traditions and in Scripture. Although faith transcends pure reason, there are certainly good solid foundations for believing that God is revealing himself to us. It is firm in the Christian traditions that God also reveals himself in everything he made in Creation: in personal creation and in objective non-personal creation. If that is the case, why should I not use my best scientific knowledge of creation to try to get an idea of God, the Creator? It will be only a glimmer, a shadow. It, nonetheless, reveals a God who made a universe that has within it a dynamism, whereby in a dance it leads from stardust to life. The universe thus participates in the very creativity of God. If they respect the results of modern science, religious believers must move away from the notion of a dictator God, a Newtonian God who made the universe as a watch that ticks along regularly. Perhaps God should be seen more as a parent. Scripture is very rich in this thought. It presents, indeed anthropomorphically, a God who gets angry, who disciplines, a God who nurtures the universe. Theologians already possess the concept of God's continuous creation. To explore modern science with this notion of continuous creation would be a very enriching experience for theologians and religious believers. God is working with the universe. The universe has a certain vitality of its own like a child does. You discipline a child but you try to preserve and enrich the individual character of the child and its own passion for life. A parent must allow the child to grow into adulthood, to come to make its own choices, to go on its own way in life. In such wise does God deal with the universe.

These are very weak images, but how else do we talk about God. We can only come to know God by analogy. The universe as we know it today through science is one way to derive analogical knowledge of God. For those who believe modern science does say something to us about God, it provides a challenge, an enriching challenge, to traditional beliefs about God.