

## AAAS Dialogue on Science, Ethics, and Religion (DoSER) Public Lecture March 27, 2006

### **The Dance of the Fertile Universe: Chance and Destiny Embrace**

George V. Coyne, S.J. Director, The Vatican Observatory

#### **SUMMARY**

When talking about evolution in a very broad sense there is a classical debate about chance and necessity. “According to Modern Science,” declared George V. Coyne, Jesuit and director of the Vatican Observatory, “the debate is mistaken.” What is missing in the debate, he argued in his lecture on March 27, 2006 presented in the series sponsored by the AAAS Dialogue on Science, Ethics, and Religion, is “the fertility of the universe.” The evolution of the universe is propelled by fertility as well as chance and necessity, he proposed.

If the universe evolved only by chance, then there would be no place for a God of purpose. If the universe evolved only by necessity, this might tend to lead to an affirmation of God. But if it evolves due to both, then, he said, “we are caught in between.” Coyne used this point to emphasize that in the debate between materialism and non-materialism or atheism and theism, “science is completely neutral.” This neutrality is a consequence of both the inherent limitations of the scientific method and the profound depth of human ignorance about the universe, even in the face of all the knowledge that has been gained.

To begin defining what he meant by “the fertility of the universe” Coyne offered the following numerical illustrations:

- There are about 30,000 human genes, but only about 2010 vary among human beings.
- Thus the genetic variance between human beings is  $2^{2010}$  or  $10^{605}$ .
- Each individual human can produce  $10^{605}$  different eggs or sperm.
- In the visible universe there are  $10^{76}$  atoms.

What sense does it make to compare  $10^{605}$  and  $10^{76}$ ? It is not clear, but it is a marvel, he suggested, that a universe with this number of atoms has produced such a degree of human fertility.

Of course, one of the difficulties with trying to come to terms with large numbers e.g.,  $10^{605}$ , a 1 with six hundred and five 0s following it, is that they are so far from ordinary human experience. It is helpful to use a metaphor from a more common experience of time to relate astronomical time. So, for example, if the whole 13.7 billion year history of the universe were stretched over only one Earth year, significant events in evolution would be dated as follows:

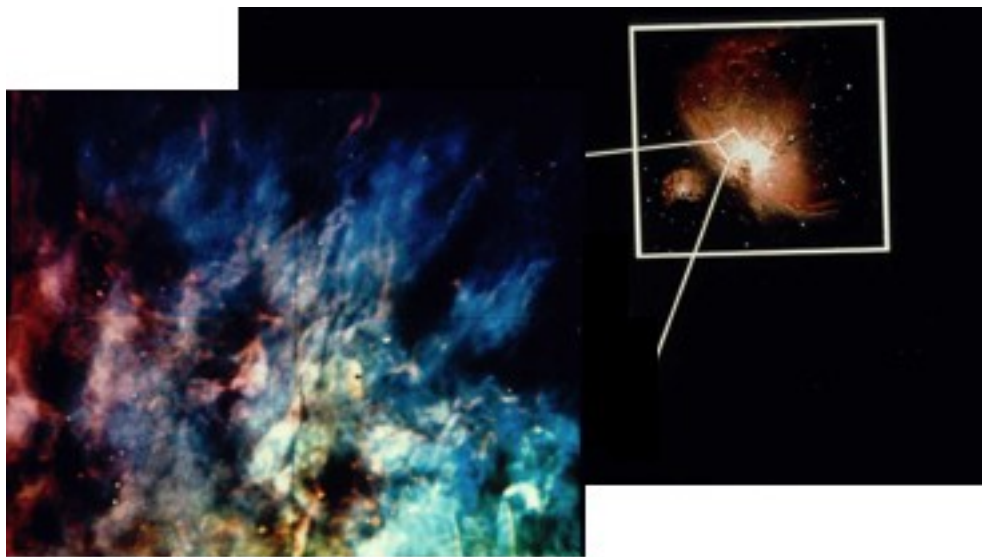
<b>Date</b>	<b>Event</b>
January 1	Big Bang
February 7	Birth of the Milky Way
August 14	Birth of the Earth
September 4	First appearance of life on Earth
December 15	The “Cambrian explosion”
December 25	Dinosaurs appear
December 30	Dinosaurs become extinct

The last day of the year is a very rich one.

<b>December 31</b>	<b>Event</b>
7:00:00 pm	First hominids
11:58:00 pm	First humans
11:59:30 pm	Age of Agriculture
11:59:47 pm	Building of the Pyramids
11:59:58 pm	Jesus is born
11:59:59 pm	Galileo is born
12:00:00 Midnight	Today

If you look at cosmic history this way, all of modern science happened “in the last second.” Coyne concluded, “So, if there are a few gaps in our knowledge [of how the universe works] – if there is some ignorance – give us more time; we’ve only had one second.”

Before reviewing how cosmologists see the universe today, Coyne noted that he would also ask what such a view of the universe could mean to a religious believer. He offered an important distinction. Speaking personally, he indicated, “My religious faith did not come about by any strictly reasoning process – certainly not from science. I did not come to believe in God. God gave himself or herself to me.” For him religious faith “is a free gratuitous gift and it is a personal relationship not just a rational relationship. “God,” he declared, “is not a God of explanation but a God of love.” It is only after the “moment of personal relationship” that the question of the meaning of “God” arises, and how our understanding of the universe bears on this question.



Orion Nebula

Coyne showed a slide of the Orion Nebula with its distribution of red gas to the left, blue gas to the right and various points of incandescence. All might agree that it is a pretty picture, but scientists want to know what it means. As it turns out, the red gas indicates a stellar womb, an area where stars are being born. The first stars born in such an area are large and energetic and because of their nearness to the gas in that area, the energy they radiate is, by the ordinary laws of chemistry and physics, absorbed by the gas. The gas is mostly hydrogen and reradiates the energy in hydrogen’s area of the spectrum; namely, the red region. The blue area of the nebula is blue for the same reason that the sky is blue; the molecules of gas and dust particles in that area are farther away from the source of energy and so reflect and scatter the energy rather than absorb it.

The Orion Nebula is in the Andromeda Galaxy, a spiral galaxy similar to our own. It is about 100,000 light years across and contains the mass of what would be, on average, 100 billion stars like the Sun. Coyne pointed out that we never see things as they are but as they were in the past. This is not a matter of “philosophy or epistemology but of physics.” Light moves at a very high but nevertheless finite velocity. When we look at the moon we see it as it was 8 seconds ago and when we watch the Sun set, it has set 8 minutes earlier. Andromeda is 2 million light years away so we see it as it was 2 million years ago.

In a 13.7 billion year old universe a few million years is not much time. But because looking out into space is also looking back into time, astronomers are able to piece together a general outline of cosmic history stretching backward from the present by observing the nature of objects at ever greater distances away from the Earth. The Hubble telescope has made it possible to observe galaxies 12 billion light years away, as they existed less than 2 billion years after the Big Bang.

Coyne then asked rhetorically, “How are stars born?” and provided a brief description of star formation. A cloud of cosmic gas and dust begins to fragment due to the interplay of gravity and magnetic fields. Following the law of gravity each fragment begins to collapse. Such fragments can have a mass ranging from the mass of the Sun to 50 times that mass. Following the gas laws, as the cloud collapses it also heats up. As the heat builds up to millions of degrees, a thermonuclear furnace is ignited in which light elements are converted into heavier elements. The process begins by converting hydrogen into helium, then conversions to carbon, oxygen, and nitrogen on up to iron. Iron is the heaviest element to be produced in the stars. Heavier elements on the periodic chart are produced by different, non-stellar, and later processes of nuclear chemistry. The more massive the star the heavier the elements it can produce. The greater the mass collapsing, the greater the heat is that will be generated.



Ring Nebula



Crab Nebula

Coyne next showed a slide of a dead or dying star (Ring Nebula). At the center of the image is a white dwarf star and surrounding it, what looks like a smoke ring, is the star's atmosphere which has blown off in the star's final collapse. The next slide was of the remnants of a supernova that is known as the Crab Nebula. When a star has a mass of 5-10 times that of the Sun and goes through the final process of collapse, it produces a cataclysmic explosion that scatters all but a remnant neutron star out into the surrounding cosmic neighborhood. In their dying, these stars blow out enriched material, the heavier elements they have produced. Immediately after the Big Bang hydrogen was the predominant element, but with the death of the first generation of stars the material composition of the cosmos became enriched.



Vail Nebula

Showing a slide of the Vail Nebula, remnants of a supernova that occurred about 100 million years ago, Coyne noted that dying stars seed the next stellar generation. So that over time with each new generation of stars, the universe, in a sense, is getting heavier. The total mass/energy has not changed but the distribution of the mass is changing toward the heavier elements.

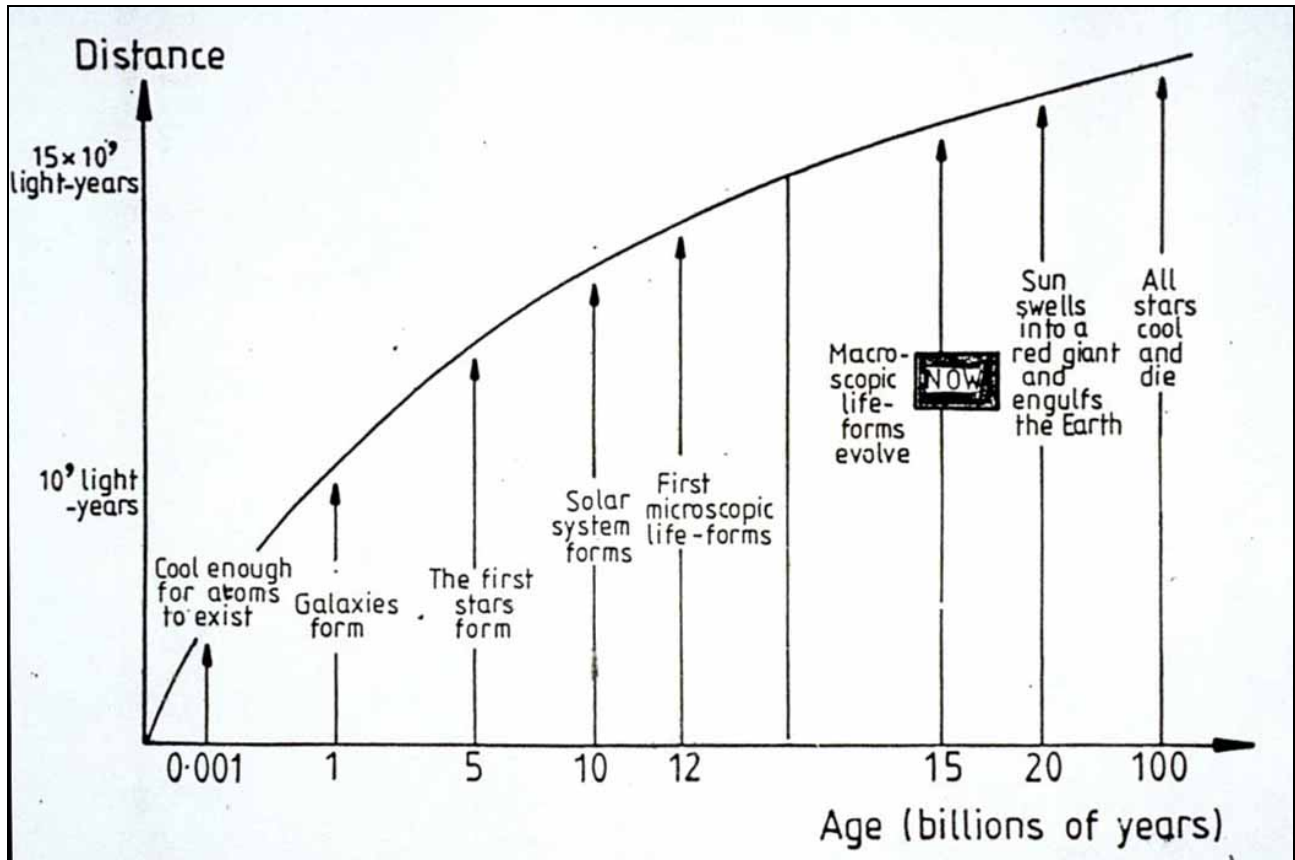
“Why,” Coyne asked rhetorically, “spend time on the birth and death of stars? Because, if this did not go on we would not be here. That is a scientific fact.” Without the heavier elements we would not have the chemical abundance needed for life. We really are born of stardust.

The next stage of cosmic development involves the development of planetary systems around stars. These are composed of the heavier elements produced through the lives and deaths of earlier generations of stars. We know, of course, that the Sun has such a system but we also know today that at least 150 other stars have planets which revolve around them. These 150 systems have been discovered by surveying only about 1000 stars. The search has been limited to the “solar neighborhood” due to the limitations of current observational techniques. However, the evidence suggests that planetary formation may be a frequent event in the history of the universe.

Beyond this, Coyne noted, “scientists are very hesitant to say that there is life out there in the universe.” There are the conditions for life but that is not the same thing as finding life itself or knowing that life exists elsewhere than the Earth. This uncertainty is due in part, he suggested, because we do not currently know how life began on Earth.

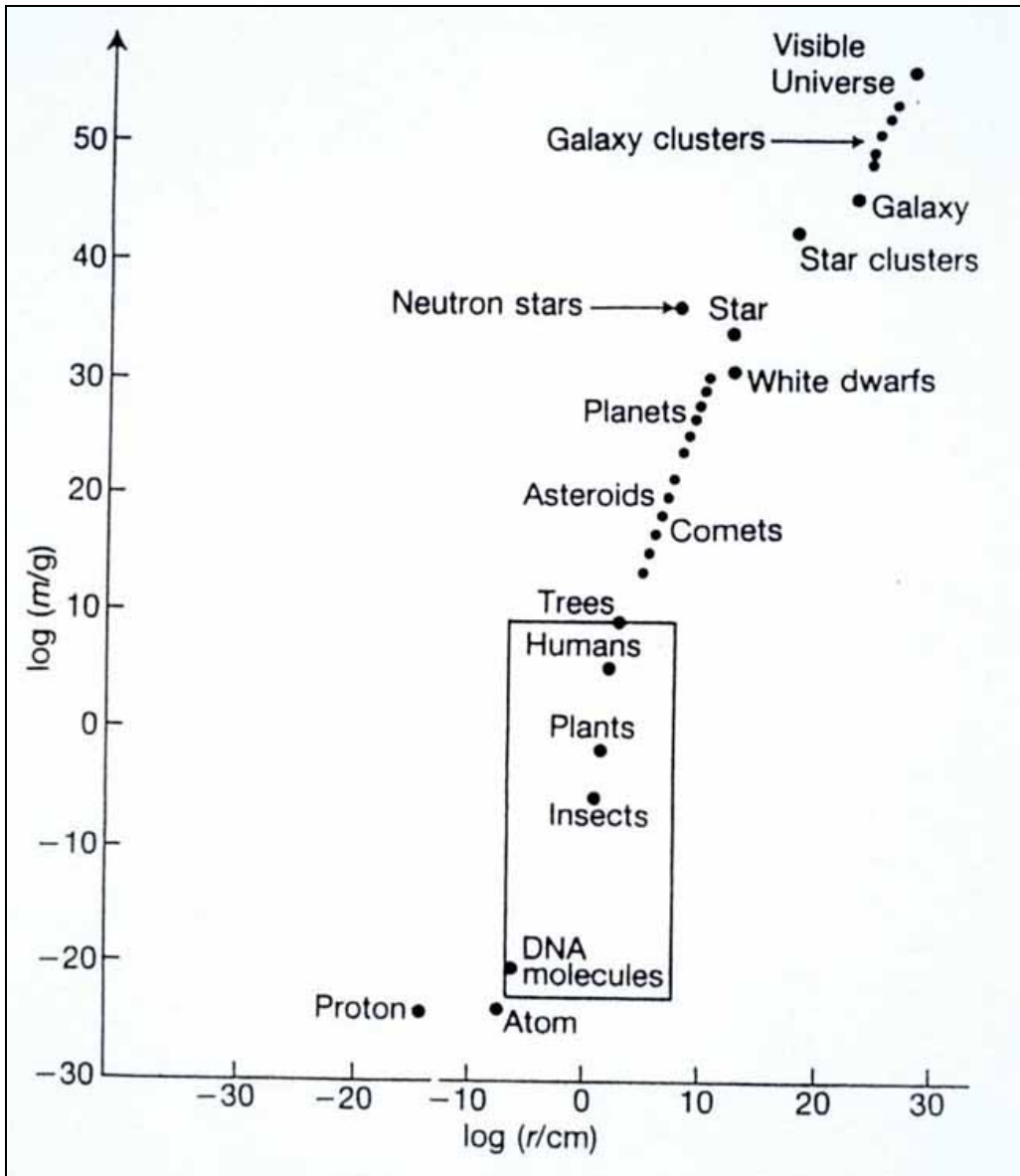
Showing a picture of the Earth, Coyne said, “Out of all of this came this little grain of sand.” He went on to declare that “scientists don’t appreciate what happened on this grain of sand in the 17<sup>th</sup> century.” With the rise of the modern sciences from that time, human beings have come through research in the various sciences to be able to put the universe in their heads. Humans are able today to say with confidence that the universe is 13.7 billion years old  $\pm 0.2$ . This is a remarkable accomplishment.

“But,” Coyne asked, “What does this say to the religious believer?” To answer this question he showed a graph that plotted the size of the universe in light-years against its age.

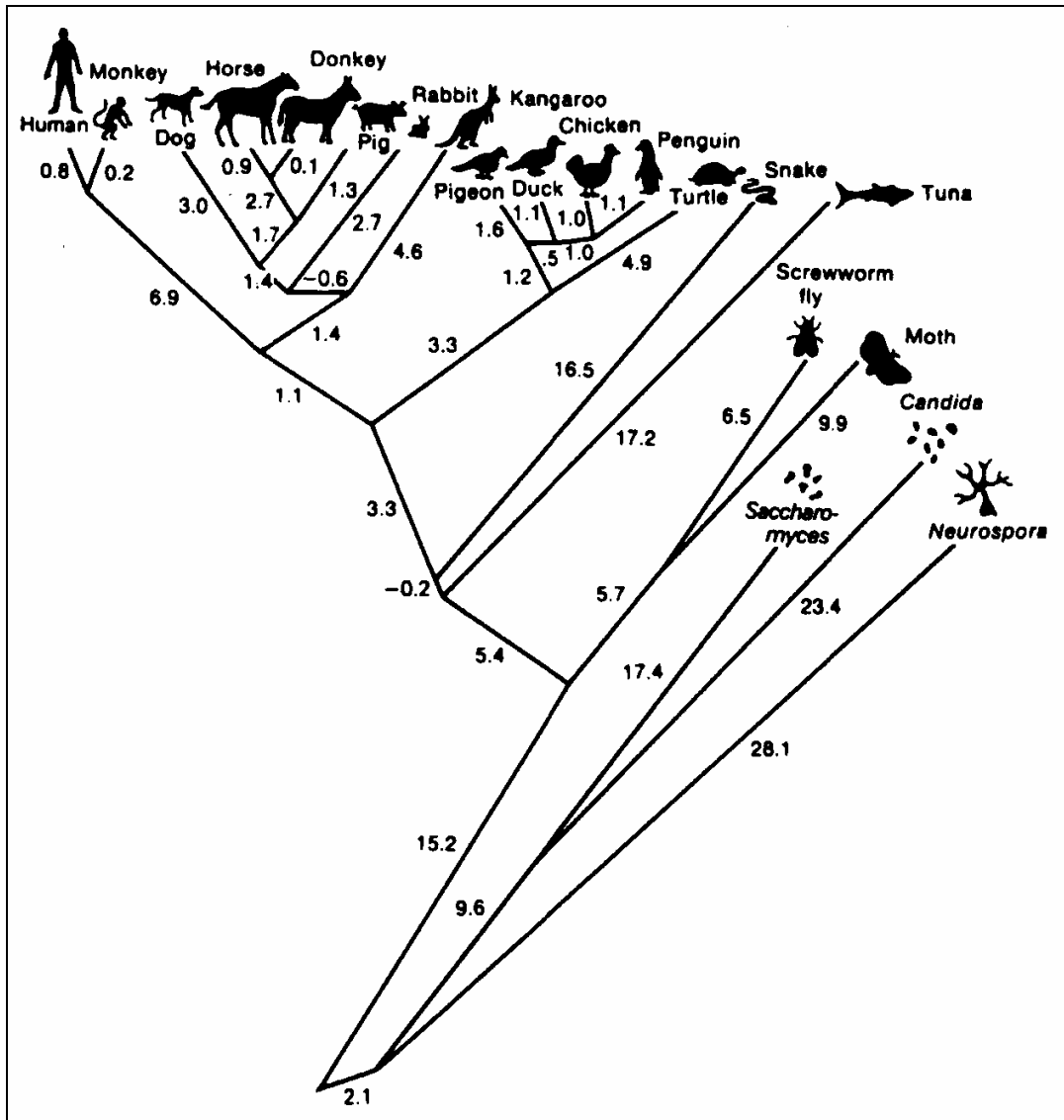


“Why,” he asked, “did it take 12 billion years to build an amoeba?” The answer is because the universe did not have the necessary chemistry until the third generation of stars. The Sun is a third generation star, it is about 5 billion years old and is about half way through its life cycle.

Coyne showed a second graph, this time plotting (using log/log scales) the mass of objects against their size.

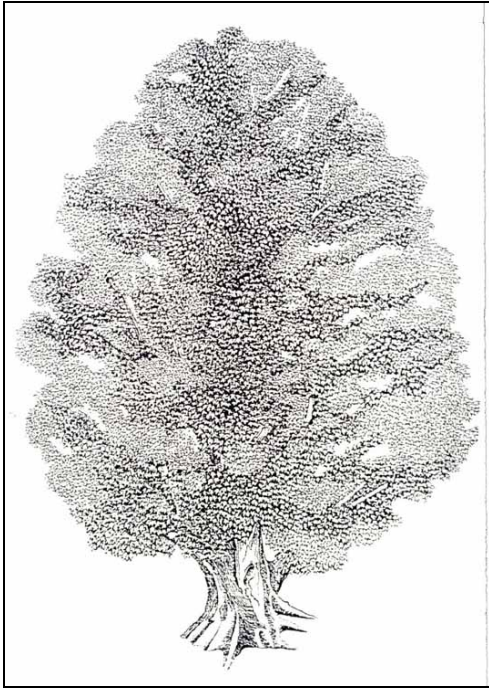


This graph does not prove but does indicate that “humans come out of the universe just like everything else. We fit the pattern of products.” Another kind of pattern illustrating the same point can be seen when comparing the number of mutations in a protein common to a wide range of creatures from neospores to humans.

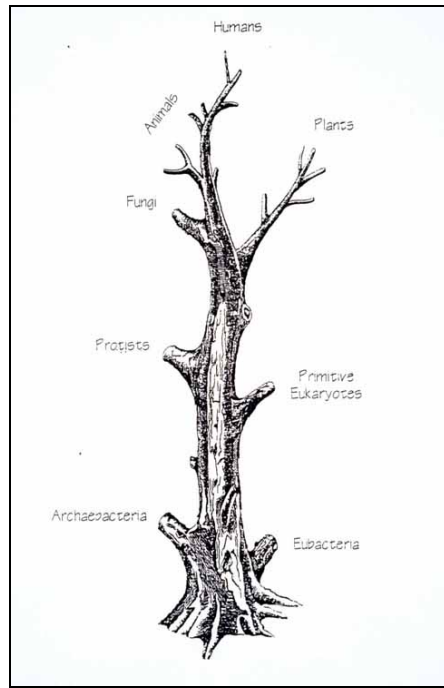


Again, while not proof, this pattern from molecular biology indicates an evolutionary process that has led to the emergence of all living things. This sort of comparison can be made with a number of different molecules. It is part of the scientific evidence that absolutely well establishes an evolutionary understanding of the history of life on Earth.

Returning to the issue of chance and necessity Coyne used two tree images to illustrate his point.



The Tree of the Universe



The Tree of Life

In the first tree, “the tree of the universe,” none of the failed processes, the dead leaves and dead limbs, have fallen off. By “failed processes,” Coyne said, he meant all of those opportunities when something might have happened but did not. For example, if two hydrogen atoms meet in the universe, by the laws of nature (necessity), they have to make a hydrogen molecule. But due to the particular pressure and temperature at their spot in the universe, they may not (chance). They wander in the universe meeting trillions of times and there are trillions of atoms doing this. “So,” Coyne asked, “why be surprised that a few hundred or a few billion times a hydrogen molecule is created?” Just by virtue of a fertile universe giving so many opportunities for atoms to meet and combine, the outcome is not necessary but is inevitable.

Coyne noted that Albert Einstein, objecting to the statistical character of quantum mechanics, quipped that “God does not play dice” with the universe. Christian de Duve, the eminent molecular biologist, has commented that Einstein was mistaken. God does play dice, but God loads the dice. Coyne, on the other hand, offered a different way of thinking about chance and necessity in the universe.

Imagine that a person plays the lottery and wins. That person would be surprised, he suggested. But say that person plays the next week and wins again. There would be less surprise. And if she continued to win week after week for 52 weeks, she would be very happy but not at all surprised. She would rightly conclude that the lottery has been fixed in her favor. Her winning is not really a chance but a necessity.

But suppose she played the lottery several billion times over a long period of time and won a few hundred times. Statistically, she should not be surprised. And this, said Coyne, is how the universe works. The game is played so often that if you blow away all of the dead leaves and branches from the tree of the universe, what you get is “the tree of life” or something like it.

Coyne insisted on the phrase “something like it,” suggesting the inevitability of the process but not its necessity. To use the word “necessary” would be to deny the chance elements that are a part of the process. The branching on the tree of life could be different due to the chance processes involved.

This notion of inevitability and avoidance of necessity is what the religious believer needs to grasp because this is how the universe appears to be scientifically, “a universe of chance and necessity meeting in a fertile circumstance.”

“Why,” Coyne asked, “is the human being at the top of the tree of life?” It is because, he suggested, the human brain is the most complex machine that we know. “We put ourselves there not out of ego but out of ignorance. We know of no more complicated thing.”

Coyne closed his talk by turning to the question: “If I believe in God, what does this sort of fertile universe say about God?” First, he stated, it does not prove that God exists. This, in his view, is the false premise that underlies the intelligent design movement (ID). The universe seems to exhibit an intrinsic destiny in the process of evolutionary complexification through natural processes. But recognizing this does not require that a person believe in God nor does it lead to belief in God. It only has religious repercussions *if* I believe in God. The process does

not need reference to God to explain it, which is what, he judged, ID wants to do. ID wants to say that there are some biological organisms or processes so “irreducibly complex” that they could not be built up by the interplay of chance and necessity in a fertile universe. “To my mind, this is wrong,” Coyne declared.

But again, what does such a universe say about God? First, admitted Coyne, this universe is not the creation of the God in which he once believed. This is not to say that science has led him to deny his faith but it has stimulated the evolution of his religious belief. If the believer takes the universe as described by science seriously, then God did not make a predetermined universe, all set up in advance, deciding everything that was going to happen. The universe shares in God’s creativity. This, Coyne emphasized, was a religious sentiment but one that was based upon his knowledge as a scientist. He concluded, “The universe shares the creativity of God in a very real way through the evolutionary process.”