Chapter 28 Life in the Universe

Cosmic Evolution

Figure 28.1 shows the 7 major phases in the evolution of the universe: particulate, galactic, stellar, planetary, chemical, biological, and cultural. These 7 make up what is called *cosmic evolution*. Up to now in the book we have studied the first 4 and now we will discuss the last 3 parts. The universe has evolved through each of these phases to get where we are today. We are the results of an incredibly complex chain of events over time. This lends itself to the question: are *we alone in the universe?* In this chapter we will discuss the possibilities.

Life in the Universe

To understand the concept of life, we must first know what it is. Unlike the physicist who can tell you the difference between matter and energy, the biologist can't do that. Most scientists do agree on the following:1) they can react to their environment; 2) they grow by taking in nourishment; 3) they can reproduce; and 4) they can evolve over time. These rules are not strict though. A star can react to gravity, accrete material from their neighbors, generate energy and reproduce by triggering star formation. A virus is inert until it gets into a host and then it turns on and starts reproducing, exhibiting all the properties of life even though it is not living. The general case in favor of extraterrestrial life is summed up in the assumptions of mediocrity: 1) Because life on Earth depends only on a few molecules, and 2) because the elements that make up these elements are common to all stars, and 3) if the laws of science apply to everything in the universe, then, given sufficient time, life in the cosmos should have begun elsewhere. The opposing view is that intelligent life on the Earth is due to a series of fortunate accidents.

Chemical Evolution

One of the problems that we have is that we don't have any evidence for the earliest Earth. The first billion years or so of the Earth was wiped out by geological processes. Volcanoes released gases rich in nitrogen, hydrogen, and carbon compounds, but very little in the way of free oxygen. As the Earth cooled ammonia, methane, carbon dioxide, and water formed. Large amounts of energy were provided by radioactive elements, lightning, volcanism, ultraviolet light, and meteorite impacts. This energy then helped form the gases and water into amino acids and nucleotide bases. These are the building blocks of life as we know it. Amino acids build protein and the nucleotide bases build genes which are parts of the DNA. These genes help transfer the genetic material from one generation to the next through reproduction. The idea that complex molecules could have evolved naturally has been around since the 1920's. In 1953 an experiment was done, Figure 28.2, to show this could have happened. A mixture of gases thought to be similar to the primordial soup, water, methane, carbon dioxide, and ammonia, was mixed up and it was energized by an electric discharge. A few days later the mixture was analyzed and it was found that many of the same amino acids found in all living things were found in their setup. About a decade later scientists were able to repeat the experiment and produce nucleotides. We have shown that we can take nonbiological material and form the building blocks of life. Under the influence of heat we have synthesized the amino acids into blobs of protein that isn't water soluble. Figure 28.3 shows some of these protein blobs called *microspheres*. Are these microspheres alive?

NO! But they do contain the basics for life to form. They lack the DNA. IN figure 28.4 you can the similarities between ancient cells and the microspheres.

An Interstellar Origin?

Recently a view has arisen that this couldn't have happened this way because there wasn't sufficient energy available in the atmosphere to power these events. They suggest that the material that formed the first known complex molecules may have come from interstellar space. Several pieces of evidence seem to support this. There are reports of at least one amino acid in space. This has not been verified. NASA tried to reproduce the experiment and produce organic material. What they got is in figure 28.5. When they placed the irradiated ice into water they found that the ice had formed droplets surrounded by membranes and containing complex organic material. No amino acids, proteins, or DNA was found in the mix. But we know that the cold harsh environment of space could form these. Icy stellar grains are thought to have come from comets. Large amounts of organic material was detected on Halley's Comet as well as Comet Hale-Bopp. The meteorite fall in Murchison, Australia in 1969 contained evidence for 12 of the amino acids found in living cells. Some people said that they were contaminated from the Earth, but some of the amino acids are not found on the Earth. If nothing else we can argue that the amino acids can evolve in space. The big question is whether this where the primary material came from to form life.

Diversity and Culture

We now know that life did appear on the Earth and from the fossil record we can see how it has diversified over time. Blue-green algae appeared about 3.5 billion years ago and then about 2 billion years ago the amoebas appeared. Around 1 billion years ago the sponges appeared and then life began to flourish. The fossil records show how life has changed through the years. Scientists accept the reality of *biological evolution*. As the surface of the Earth changed, organisms that could best take advantage of the conditions thrived and others died off. What led to these changes? Chance! An organism just happened to have some trait that made them more likely to survive than others. It is thought that intelligence is strongly favored by natural selection. A man that could learn how to use tools would be a step above someone that couldn't. Probably the biggest development was that of language. This allowed for coordination while hunting or seeking protection. As we get closer to modern man *cultural evolution* occurred. This is the changes in the ideas and behavior of society. Most of what we have today was created by our ancestors in the last 10,000 years.

Life in the Solar System

WE have an understanding of how life has changed on the Earth. But has life found a foothold on any other planet or body in the solar system? We will try to examine this possibility.

Life as We Know It

The term "life as we know it" means a carbon based organism that originated in water. We know that Mercury and the Moon don't have water so we don't expect to find life there. With no atmosphere both of these worlds are bombarded with high energy radiation from the Sun which would prevent any complex molecule from forming. The jovian worlds have no solid surface and Pluto, like most of the moons of the outer worlds, is too cold. One exception would be the moon Europa that is thought to have a liquid ocean under the ice. Another possibility would be Titan where the atmosphere contains many of the important molecules for life. Of all of the other bodies, Mars is the one where we really believe life may have been at one time. Currently it is quite harsh, but in the past it is thought that water was on the surface and it was a nice place to be until it lost its atmosphere. So far we haven't been able to find any evidence for life on Mars, at least not yet. We shouldn't rule out life due to extremes in temperature. We know of life around thermal vents in the ocean where life has been found in water that is 100º C.

Alternative Biochemistries

Who knows in what form life may be found? How can we assume life would all be carbon based? We can't assume this. And since that is true, actually finding life elsewhere may be very difficult.

Intelligent Life in the Galaxy

Humans seem to be the only intelligent life in the solar system. But our solar system is only one very tiny part of our galaxy. Can we estimate whether any life exists elsewhere? Let's look.

The Drake Equation

An early way of looking at the possibility of life in the universe was by using the *Drake Equation*. Several factors in this equation are purely a matter of opinion. Let's look at parts of the equation.

Rate of Star Formation

Since the Milky Way has at least 100 billion stars and our Sun will live for 10 billion years, it is thought that we can produce about 10 stars per year. This is probably a reasonable number.

Fraction of Stars Having a Planetary System

Many astronomers believe that planetary formation is a consequence of stars formation. We now know of more than 140 planets around other stars, but they are all Jupiter sized bodies and none have been Earth sized. But it still means that the condensation theory is a viable way of planet formation. Astronomers think that most stars have planets.

Number of Habitable Planets Per Planetary System

How many planets will be acceptable for life to form? That depends on the star's stellar *habitable zone*. This is the area around the star that would be right for life to form. Maybe close enough for the planet to have liquid water. Venus, Earth, and Mars are probably in the habitable zone around the Sun. But Venus and Mars have both undergone major changes to their atmosphere that makes them unlikely for having life. The galaxy can affect life. If a star is in part of the galaxy where there is very little star formation going on, then you will find that this part of the galaxy lacks the heavy elements necessary for planet formation and could not harbor life. One other thing is that about 50 % of the stars we see are binary stars. Planets couldn't survive the pull of 2 stars. It would probably be thrown out of orbit.

Fraction of Habitable Planets on Which Life Actually Arises

There is a tremendous number of possible combinations for the atoms to bind together in and form complex molecules. If it was random, then it is unlikely that they would have formed into molecules that gave rise to life. In fact it is close to zero. But we know that certain combinations are favored over others. Of the billions of combinations, only about 1500 organic groups occur being made up of only about 50 simple building blocks. This means that molecules that give rise to life are not assembled by chance alone.

Fraction of Planets on Which Intelligent Life Develops and Uses Technology

For this factor we need to estimate the probability that life will develop a technological competence. We know that our culture arose from several civilizations on Earth, not just one. We just don't know how many cultures will develop the technology needed to contact us.

Average Lifetime of a Technological Civilization

As we move from the left to the right in the Drake Equation, the reliability of each one goes down. The last factor, the longevity of a technological civilization, is completely unknown. One thing is known for sure: if any one of these factors in the equation is very small, then the number of intelligent civilizations out there is small. If a civilization would last about 1000 years, then there should be about 1000 civilizations in the galaxy. Even if there are other civilizations out there and they are like us, the sheer size of the galaxy prevents us from contacting them.

The Search for Extraterrestrial Intelligence

Let us continue the idea that we are not alone in the universe. The big question then is how do we contact our neighbors?

Meeting Our Neighbors

Lets us assume that a civilization lasts for 1 million years, which means that there should be 1 million civilizations out there. That means that each would be about 30 pc apart or about 100 light years. That means that 2 way communications would take 200 years. One way to communicate would be to travel far outside the solar system. At our fastest speeds it would take about 300,000 years to reach Alpha Centauri. On our Pioneer 10 space craft we placed a plaque on the craft showing who we are and where we are. Figure 28.13 It is now well beyond Pluto on its way out of the solar system. Voyager 1 and 2 are both doing the same thing. Now the argument is that we may be one of the youngest civilizations in the galaxy and when some of the older ones hear from us they may act like us and want to dominate us. Regardless we should be cautious.

Radio Communications

A cheaper way of finding others out there would be to listen for them to call to us. Since long wave radiation seems to move through the galaxy without being affected radio seems the logical choice. Where should we look? We should target all F, G, and K type stars. Another big question is how we distinguish their signals from the background radio noise. Consider how the Earth would look to someone else. Figure 28.14 We are broadcasting constantly. We are a better radio source than is the Sun.

The Water Hole

Since the most abundant element in the universe is hydrogen, then maybe we should communicate in the 21 cm range which is the hydrogen wavelength. At 18 cm we have the –OH molecule. These 2 form water. Maybe we should watch between the 18 and 21 cm branches. This is called the *water hole*. This is only a guess, but it seems like a good one. One of these searches is called SETI or the search for extraterrestrial intelligence. Large radio antennas are being used to listen to millions of channels. Figure 28.16