Prologue: The Earth: As You Like It?

That every eye, which in this forest looks,
Shall see thy virtue witness'd everywhere.

As You Like It, Act III. Scene II.

A poor virgin, sir, an ill-favoured thing, sir, but mine own

As You Like It, Act V. Scene IV.

William Shakespeare (1564–1616)
The Oxford Shakespeare, 1914

Questions have arisen since the dawn of history. Is the Earth an ideal place for the benefit of mankind? Is it a mediocre or even cursed place where we are destined to live? Are we alone? Are there a vast number of inhabited worlds?

Philosophy and religion addressed these issues before the late sixteenth century, but there was no evidence one way or the other. Rationally, one could believe what one wished. In Western Europe, religious authority demarcated acceptable philosophy. The concept that the Earth exists for the special benefit of mankind was dogma. Events occurred for our reward and for our chastisement.

That all changed when Giordano Bruno (1548-1600), a runaway Italian monk, proposed that the Sun is a star and the Earth is a planet. Discussion based on observations was dangerous to worldview of the Church (and, as it turned out, to Bruno) because it trained the crosshairs of the coming scientific revolution on the cozy medieval cosmos.

In the subsequent four hundred years, science has not resolved several of the key issues raised by Bruno. In modern scientific terms: Is the Earth a very rare, special place where intelligent life could evolve? Is it just a run-of-the-mill planet? Is intelligent life

common or rare in the universe? Is microbial life common or rare? We have not detected extraterrestrial intelligence. We have not even found unequivocal signs of microbes on another planet.

Worldviews and sampling biases. Given this profound ignorance, worldviews continue to influence astrobiology. A variety of worldviews is useful in that it fosters a diversity of ideas and approaches. Still modern science does not base its conclusions on wishful thinking. It is nice to believe that mankind is special, but we are much like the flea that thought his skunk the best smelling animal in the woods because it was the only animal he had ever been on. It is also nice to think there are vast numbers of intelligent aliens from which we have much to learn, but *Star Trek* is not a documentary.

It is easy to see why the concept of special benefit, called "the Strong Anthropic Principle" by modern philosophers, beckons. The Earth suits us well and we are well suited for our life on the Earth. Even our daily lives give the sense of good luck and in trying circumstances miracle.

For example during college, you were returning home early across a plaza to get ready for a rock concert. The day was hot. You paused to purchase a soft drink. A deafening crash with flying shrapnel knocked you to the pavement. You staggered to your feet and viewed the remains of a harpsichord on top of a pretzel vender's stand blocking your intended path. The rope attaching the instrument to a helicopter had snapped. You may be tempted 30 years later to view your survival as a miracle and see that a higher purpose allowed you to survive and develop an effective treatment for nasal cancer. Thinking further back, your family tradition recounts the numerous close calls of

your ancestors.

However, miracles occur in retrospective. Having minor abrasions, painful shrapnel wounds, and ruined clothes in 5 minutes was not at the top of your list of miracles when you entered the plaza. No one lives in such dire trepidation of falling harpsichords that they regard safe passage across a plaza without being crushed by one to be miraculous. In fact, most people do not even anticipate the presence of a harpsichord at a rock concert. Only survivors have the luxury to look back. In this case, the young engineering student manning the pretzel stand had no chance to lead the first sample return from Mars or even to speculate about his demise.

Returning to astrobiology, our own existence provides meager insight into whether life is rare or common in the universe. Life must arise for intelligent life to speculate. We cannot expect to find any incidents in our personal or species history that would preclude our presence. Scientists willingly invoke this sampling bias, "the weak anthropic principle," when they understand the science. They are typically reluctant to invoke it when they do not. Nineteenth century divine providence arguments can be turned around into weak anthropic ones. For example, the Creator placed swift streams and coal beds in England because he wanted the Industrial Revolution to start there. Rather, an industrial revolution based on water and coal power will tend to begin in a land where both are abundant.

Generalizing further, much of the progress of science over last 400 years has involved collecting representative unbiased data. Laboratory scientists routinely conduct controlled experiments. The astrobiologist can control, for example, where she points her telescopes or where she searches rocks for signs of ancient life on the Earth, but we have no control

over where we find ourselves in space and time. She must try to recognize implications of this bias and then proceed.

Astrobiology today. The number of scientists actively studying the habitability of planets is small, not much greater than that in the time following Bruno. In their book *Rare Earth*, Peter Ward and Donald Brownlee list Michael Hart, George Weatherill, Chris McKay, Norm Sleep (b. 1945), Kevin Zahnle, David Schwartzman, Christopher Chyba, Carl Sagan, David Des Marais, and Jim Kasting; a total of a dozen including the 2 authors. Scientific conferences on astrobiology have a few hundred attendees. Unlike Bruno, we are backed by countless other scientists.

Modern studies of planetary habitability involve all physical and life sciences. At the forefront is astronomy. It has provided hard evidence since the time of Bruno, most recently with the detection of thousands extrasolar planets. The space program has brought images and surface analyses of solar planets, making planetary science a branch of geology. Astrophysicists have determined the means of the formation of stars and planets and the life history of stars. Evolution yokes terrestrial geology and biology into a unified field but we are only able to export generalities to other planets.

At one level, studies of planetary habitability involve the most advanced technology and sophisticated orbital dynamics, astrophysics, atmospheric chemistry, biochemistry, inorganic chemistry of rocks, and evolutionary biology. Fortunately, the layperson can understand the basic issues and techniques, for example even the use of calculus to obtain planetary orbits. You can see many fundamental astrobiological results for yourself without sophisticated equipment.

The intent of this book is to illustrate how science functions in practice, as well as its results. Everyone knows that science is limited by technology; for example, we cannot easily retrieve rocks from Mars. It is also limited by our inability to do computations and our inability in mathematics. I'll show that a lack of imagination frequently limits scientific progress as well.

Working scientists, economists, and engineers whose business is imagination still fail in this regard. Blatant failures provide lessons and earn the pejorative "linear thinking." Their work is not easy. For example, many people 25 years ago thought that the world would now suffer from a dire dearth of copper. The vast population of China, India, and the Third World would become prosperous and want telephones. There would not be enough copper to string wires. Rather, cell phone technology made phone wires obsolescent. Much of the world will never be wired. In fact, the demand for copper waned so much that the School of Earth Sciences at Stanford no longer offers courses on how to find more of it in the ground. Yet this action may have been premature, copper prices have since risen to the point that it attracts thieves.

Organization of this book. The focus of this book is astrobiology, the first "new" science of the Renaissance. Modern science started with this subject yet there are lots of things we do not know, starting with the fact that we have no confirmed astrobiota. There are other topics that we know adequately, some for over 300 years. More is being learned in these fields all the time, but our ignorance elsewhere precludes its application. Astrobiologists need to know what they need to know at what level. To do this, they need to know what they do and don't know.

In astrobiology, we have a good grasp on the vastness of space and time. For example, the Sun will become a red giant star in 5 to 6 billion years. Astrobiologists would take little notice of an accurate calculation by an astrophysicist that the time will be 5.6893 billion years. They simply cannot apply the added information to the habitability of the Earth and the habitability of planets in general. Neither would you use a measurement that your door is 3,020.679 meters from the door to your work any differently than a measurement of just 3,000 meters. On the other end, finding life or even fossil life on say Mars would revolutionize the science. It would immeasurably influence our collective worldview.

The historical perspective in this book shows how science functions particularly in regard to the feedback between worldview and science. In each field, endeavor begins with ignorance, false starts, missteps, and occasionally religious dogmatism. Individual scientists may be more or less correct on some issues and off base on others. Scientists are people, prone to egotism, bias, and sloth. As more is learned, issues get solved in principle. The data and methods may still leave a lot to be desired, but practicing scientists know what needs to be done. Improvement becomes routine and knowledge is refined like additional decimal places on numerical results. At that point I cut off historical discussion and jump to the modern results. My scientific career has spanned over 1/10 of the 400 years of modern science. I thus provide recollections to illustrate points.

We continue with astrobiology rising at the dawn of modern science.