Questions for study V
(be prepared to discuss Tuesday, May 2, and turn in these questions thereafter)

Ward and Brownlee, The Life and Death of the Planet Earth

1. (page 180) Name **two assumptions** being made here about radio waves.

First, that distance is the only reason that the waves’ energy dies off with distance. In point of fact, dust and gas clouds can absorb radio waves and thus prevent them from getting very far away at all. Second, that the aliens would necessarily know how to decode any modulated signal and interpret it as a form of communication. You may have seen a printout of a voice recording; unless one were to know to vibrate a speaker in exactly the manner shown on the printout, one would never know that the printout represented a human voice.

2. (page 183) What’s a “**pulsar**”? Why might they have been mistaken for signals from an **alien civilization**?

A pulsar is a rapidly-rotating neutron star, with a magnetic pole that directs radio waves away from the star. Thus, every time the neutron star rotates, the pole directs a “beam” of radio waves that sweep across the sky like a lighthouse beam. If we happen to be in the path of the beam, it would appear like the star was blinking on and off in a very regular fashion at us; this might be interpreted as a civilization trying to gain our attention.

3. (page 187) **Von Neumann machines** (specifically, von Neumann probes) are not really explained well here. Find a better definition of what a von Neumann machine or probe does, and **please cite your reference**.

My colleagues in the math department at Bellevue Community College put together a short web page about John von Neumann, no update date given. You can find it at http://scidiv.bcc.ctc.edu/Math/vonNeumann.html. A von Neumann machine is a machine that can execute a sequence of instructions, rather than one that can only execute one instruction or a bunch of instructions at the same time. You can see the utility of having a von Neumann machine as a probe on an alien world; it would be able to assess the terrain, determine what it needed to make more copies of itself, make copies of itself, launch the copies and the process could repeat again.

4. (page 191) The **Allan Hills Meteorite** mentioned here seems to be implicated in bringing life (microbes) to Earth. Go to an appropriate website or book (by appropriate, I mean something published or updated within the last three years) and find out what the **current status** is on whether this meteorite is thought truly to have brought microbial life to Earth. Give **one piece of evidence** of how we came to this conclusion and **cite your reference**. (Hint: the meteorite is often known by its catalog name ALH 84001).

The Allan Hills Meteorite (discovered in 1984 in Antarctica) is thought not to hold evidence for fossil bacterial life on Mars, according to the consensus view. Robert Roy Britt, writing for space.com on February 27, 2005, summarizes the current state of research on the meteorite: the mineral magnetite was found by a team of researchers to form linear structures in the meteorite.
However, they did not rule out the formation of these structures by non-biological means. That, in a nutshell, is where all of the evidence for life on Mars from this meteorite falls down: none of the evidence must have been produced by life.

5. (page 191) Time to introduce you to a wonderful resource on-line for our solar system: http://www.nineplanets.org. This site, maintained by Bill Arnett for many years, is a wonderful up-to-date compendium of all sorts of different planetary research sources. Go to the site, click on the Mars link and find another reason (apart from the reasons that Ward and Brownlee give) why Mars probably does not support life now.

Ward and Brownlee point out that Mars has little atmospheric pressure, and no oxygen, food or surface water. In addition to those reasons, Mars also is far too cold for life, and has no protection from ultraviolet rays from the Sun (no ozone layer).

6. (page 193) Ward and Brownlee claim “seventeen” extrasolar (beyond our own solar system) planets discovered “so far”. Another nice web resource is for extrasolar planetary research; it is located at http://exoplanets.org/, maintained jointly by the University of California and the Carnegie Institute of Washington. The copyright on the Ward and Brownlee book is 2002; how many extrasolar planets have been found now (up to February, 2005)? Click around the various links of this site and find out the size of the smallest extrasolar planet discovered so far is. Also find out the largest number of planets in any extrasolar system so far. Note the last two points are directly related to the Drake Equation.

As of May 16, 2006, there are 188 known planets outside of our solar system, according to the a better site exoplanet.eu (it seems that exoplanets.org is not being updated any more). The smallest extrasolar planet so far is 0.02 Earth masses (much smaller than the Earth, even smaller than the Moon) orbiting a pulsar, which is not a good candidate for a life-supporting star. The largest number of planets in any one system outside of our own seems to be four (orbiting the slightly-warmer-than-Sun star 55 Cancer).

7. (pages 195 to 197) What property or properties define:

- the inner edge of the solar system **habitable zone**
  
  the surface temperature of Earth-like planets is too hot; water boils everywhere

- the outer edge of the solar system habitable zone
  
  the surface temperature of Earth-like planets is too cold; water freezes everywhere

- the inner edge of the galactic habitable zone
  
  the energy production of stars, especially supernovae, is too high; any planetary system would be sterilized by penetrating radiation from this energy.

- the outer edge of the galactic habitable zone
the availability of heavy elements, like iron, which are critical for life; these elements become much more rare further away from the center of the galaxy due to the lower rate of star production, which is ultimately how these elements are created.

8. (page 207) Ward and Brownlee dismiss the notion of interstellar travel with the sentence “The difficulty of “practical” travel between the stars is getting there on the timescale of a human life span.” NASA’s Jet Propulsion Laboratory (JPL) in Pasadena, California, has several craft on “Interstellar Missions”. One of these is Voyager 1, the fastest and furthest human-made object, launched back in 1977. Go to http://voyager.jpl.nasa.gov/mission/interstellar.html and determine the number of years to the next stellar “close encounter” Voyager 1 will have. Does this confirm or refute Ward and Brownlee’s flippant point?

According to the site: “In about 40,000 years, Voyager 1 will drift within 1.6 light years (9.3 trillion miles) of AC+79 3888, a star in the constellation of Camelopardalis. In some 296,000 years, Voyager 2 will pass 4.3 light years (25 trillion miles) from Sirius, the brightest star in the sky” which does seem to confirm their point.

9. (page 200) This is not a question. “Terraforming” is the term applied to human engineering of Mars to be inhabitable by humans. Even though Ward and Brownlee point out the difficult aspects of terraforming Mars, it does not stop human writers from speculating about how to do so. Recent good examples of such books are the Red Mars/Green Mars/Blue Mars trilogy by Kim Stanley Robinson, Moving Mars by Greg Bear and Mars by Ben Bova. Please read these after you finish the course readings!

Davies, The Last Three Minutes

10. (page 85) Many of the stars in the night sky are part of a binary system; two stars orbiting a common center of gravity. An example of this is the bright star Sirius, which is actually a binary system of Sirius A and B. Given what is said on this page, how many trinary (three star) systems would you expect? Explain your answer.

Not a lot. The three-body gravitational problem has an unstable solution; either the third body crashes into one of the first two bodies or else gets flung off well away from the other two bodies.

11. (page 88) How does energy conservation work with a black hole, given that it emits Hawking radiation? In other words, where does the black hole get the energy to make Hawking radiation?

The ultimate source of Hawking radiation energy is the mass of the black hole itself; this is why a black hole can radiate itself into nothingness. Because matter and energy are interconvertible, the virtual particles that are created along the event horizon of a black hole, and thus have some chance of gaining enough energy to become real particles before the “energy debt” that created them in the first place needed to be paid, the black hole is forced to give up some of its mass in
order to keep these “energy debts” paid to stabilize virtual particles. Thus, over a long enough period of time, the black hole’s mass will radiate away and leave nothing behind!

12. (pages 94 through 96) Give two means by which a proton might decay into a positron.

Protons can decay when the Heisenberg Uncertainty Principle acts on the quarks within a proton and allows all three quarks to occupy nearly the same space at the same time — at that point, the gravitational force overwhelms any other force keeping them apart and they collapse into a mini-black hole, which is unstable and generates a positron.

Protons can also decay because a proton and a positron have the same electrical charge and the positron is a lower potential energy state than the proton. By the “minimize potential energy” principle of the universe, the positron should be more stable than the proton and thus protons should decay into positrons.

13. (page 98) So what will the ultimate makeup of the universe be, if all the processes mentioned in this chapter occur? There is the chilling line: “As far as we know, no further basic physical processes would ever happen.” How is the second law of thermodynamics consistent with this bleak view?

Any version of the second law of thermodynamics implies that the universe tends towards maximum entropy (disorder). By definition, disorder has no preferred orientation; in other words, an ultimate randomly-scattered set of atoms looks like and acts like any other ultimate randomly-scattered set of atoms. Without any detectable difference in these two states, there is no reason for nature to favor one over the other — and thus no need for a process to move one state to the other.

14. (page 101) Why Jeremiah? Wasn’t he a bullfrog? No, wrong reference; to which Jeremiah is Davies referring to?

Jeremiah is the Hebrew Bible prophet who is synonymous with woeful complaining, as Davies compares the people today who point out that overpopulation and dwindling energy reserves will finish humans off long before any of the endings we have spoken about do.

15. (page 102) Not a question. Note that in his estimate of how long humans have in this solar system, it is evident that Davies has not read Ward and Brownlee. To be fair, Davies published his book before Ward and Brownlee.

16. (page 106) Davies does seem to be more sanguine about our chances of colonizing space. Consider the quote: “A challenge like the human genome project, which may be a daunting task for a single generation of scientists, would be straightforward enough if a hundred, or a thousand, or a million generations arose to carry out the work.” Now consider the ten thousand years of human civilization, that has taken us from the invention of agriculture to the invention of speculations like this book. Estimate a reasonable number of years per generation (you may look at your own family genealogy), then calculate the number of generations since the invention of agriculture. Please show your calculation.

Figure 10000 years since agriculture was invented. Figure 25 years per generation, on average. Thus 10000 / 25 = 400 generations, not even a 1000 generations since agriculture!
17. (page 108) There’s this whole notion of the “energy cost” of computation. All your thought processes as well as information gathering (like seeing) are computations because your brain is moving electrical impulses from one part of the brain to another and storing it there (the definition of computation). From what source does this “energy cost” of computation arise? What do we get in return for paying this cost?

The cost arises from having to clear out memory. If every computation we did could be kept in our heads, then there would be no cost. Of course, every bit of memory is finite, so some memory must be discarded, or randomized. The randomization, translated into atomic terms, is heat. and thus, in every computational system, some of the electrical impulses is “wasted” as heat, but we do get to think in return.

18. (pages 109 and 110) This fellow Freeman Dyson seems to be hung up on the whole energy consumption by civilizations thing, doesn’t he? Find a reference on Freeman Dyson and find out how a “Dyson sphere” is one possible, albeit limited, solution for a civilization’s energy requirements. Please cite your reference.

According to Anders Sandberg at http://www.nada.kth.se/~asa/dysonFAQ.html , “The Dyson sphere (or Dyson shell) was originally proposed in 1959 by the astronomer Freeman Dyson in “Search for Artificial Stellar Sources of Infrared Radiation” in Science as a way for an advanced civilization to utilise all of the energy radiated by their sun. It is an artificial sphere the size of an planetary orbit. The sphere would consist of a shell of solar collectors or habitats around the star, so that all (or at least a significant amount) energy will hit a receiving surface where it can be used. This would create a huge living space and gather enormous amounts of energy. “

19. (pages 117 and 118) Throughout this course, we have used the terms “entropy” and “complexity” as opposites, and therefore, if complexity increases in any system, some other part of the universe must become more disordered (higher entropy) to compensate, according to the second law of thermodynamics. Davies makes a crucial distinction about forms of complexity, using as examples a bacterium and a crystal. Come up with your own example of objects or systems that illustrate these different kinds of complexity on the planetary scale or above.

The orbits of planets in a solar system are completely (or nearly so) determinable and thus represent a simple ordered system. The gravitational interaction of galaxies, though, is much more complex given the sheer number and diversity of components, and thus represents a complex ordered system.

20. (page 121) Another crossover! Pray tell, what is the nature of Martin Rees’s “eschatological study”? Using whatever source you can find, look up a synopsis or summary of Rees’s Just Six Numbers. How does this relate to his eschatological study? Please cite the reference.

Just Six Numbers refers to six fundamental constants (such as the ratio between the strength of the gravitational force and the strength of the electromagnetic force) that Rees believes determines the nature and fate of the universe. Plus magazine has a good review of it at http://plus.maths.org/issue26/reviews/book2/. It is related to eschatology, not in the religious sense, but in the ENDINGS sense; here Rees is showing that the fate of the universe is determined by the six numbers he cites that were around at the beginning of the universe.