Physics can only take us so far!

The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe. Why does the universe go to all the trouble of existing?!

- Stephen Hawking
### Brief History of Life on Earth

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4 billion years ago</td>
<td>Early Oceans formed</td>
</tr>
<tr>
<td>3.5 billion years ago</td>
<td>Cyanbacteria start releasing oxygen</td>
</tr>
<tr>
<td>2.0 billion years ago</td>
<td>Oxygen builds up in atmosphere</td>
</tr>
<tr>
<td>540-500 million years ago</td>
<td>Cambrian explosion</td>
</tr>
<tr>
<td>225-65 million years ago</td>
<td>Dinosaurs ruled (some small mammals)</td>
</tr>
<tr>
<td>Few million years ago</td>
<td>Earliest hominids</td>
</tr>
<tr>
<td>About 100,000 years ago</td>
<td>Modern humans on the scene</td>
</tr>
<tr>
<td>Less than 100 years ago</td>
<td>Humans develop radio communication</td>
</tr>
</tbody>
</table>
Life develops through evolution. Biologists have mapped the genetic relationship between all organisms, which suggests all Earth-bound life has a common ancestor.
Necessities for Life

• Nutrient source
• Energy (sunlight, chemical reactions, internal heat)
• Liquid water (or some other liquid ?)
Volcanic vents on Atlantic floor. Provides heat (energy) and mineral-rich water (nutrients). DNA studies indicate that microbes living near these are evolutionarily older than other organisms.
The peppered moth evolves in response to *industrial melanism* (genetic darkening of species in response to pollutants).

Other examples:
- diseases “resistant” to antibiotics.
- insects “resistant” to pesticides.
Radiotrophic fungi are fungi that grow on the walls of the Chernobyl Nuclear Power Plant. They convert gamma radiation into chemical energy. And they exist in an environment where the radiation level is 500 times normal exposure.
NASA scientists find bacteria that survive in Lake Mono (in California), which contains lethal levels of arsenic.
Extraterrestrial Life

Current searches for bacterial life are confined to objects in our Solar System

Mars: search for liquid water and other bacteria.

Europa: One of Jupiter’s Galilean Moons. Its surface is solid water-ice, with a liquid layer underneath.

Titan: Largest of Saturn’s moons, with possible “oceans” of liquid methane.
Liquid water will exist only at certain distances from stars with different amounts of mass (surface temperatures).

Smaller stars have lower surface temperature. “Habitable zone” will be closer to the star in those cases.
Life outside the Solar System

We define a **Habitable** world contains all the necessities for life as we know it.

It does *not* necessarily have life.

Constraints on star systems:

1. Star must be old enough to allow time for evolution (rules out high-mass stars).
2. Need to have stable orbits. (Probably rules out binary/multiple star systems.)
3. Need to have a rocky planet in the habitable zone.

Even so. There are 100,000,000,000 stars in the Milky Way. We know that at least 1 has a habitable world with life.
The Search for “Intelligent” Life?
Intelligent Life in the Galaxy

What about intelligent life?

A 1967 Soviet Union postage stamp, with a satellite from an imagined extraterrestrial civilization
Intelligent Life in the Galaxy

What about intelligent life?

Suppose other life out there that has evolved from microbes, and is now “self-aware”. And this civilization has developed radio communications. How could we find it?
Are there other Advanced Civilizations in the Galaxy?

Frank Drake worked on this problem. He founded SETI (Search for Extraterrestrial life).

In 1972, with Carl Sagan, he designed the Pioneer Plaques, a pair of gold anodized aluminum plaques placed on the Pioneer 10 and 11 spacecraft launched by NASA in 1972 and 1973. (Also worked on “golden records” carried by Voyagers.)

Pioneer 10 and 11 were the first human built objects to leave the solar system. Each carries a plaque attached to the antenna support strut (shielded from stellar dust).

Frank Drake (b. 1930)
Pioneer Plaques

- Hyperfine splitting of Hydrogen Atom
- Human figures scaled to size of Pioneer spacecraft
- Relative position of the Sun to the center of the Galaxy and 14 pulsars (with their periods denoted)
- Solar System with spacecraft trajectory
Hyperfine splitting of Hydrogen Atom

Relative position of the Sun to the center of the Galaxy and 14 pulsars (with their periods denoted)

This has shown up even in “pop” culture: http://www.youtube.com/watch?v=LOqoljl0ees

Solar System with spacecraft trajectory

Human figures scaled to size of Pioneer spacecraft
Voyager Golden Record

- Binary instructions on proper speed for rotation to turn the record
- Instructions to use stylus (included) to play record
- Relative position of the Sun to the center of the Galaxy and 14 pulsars (with their periods denoted)
- Hydrogen hyperfine splitting (used as timing reference)
- General appearance of sound waves on recording
- Scan Triggering
- Video Image showing direction of scan
- When properly decoded, first frame will look like this
Voyager Golden Record

Video Calibration Circle
Mathematical Definitions
Physical Unit Definitions

© FRANK DRAKE

1 \frac{42}{100} \times 10^9 \uparrow = 1 \text{s}

86400 \text{s} = 1 \text{d}

365 \text{d} = 1 \text{y}

6 \times 10^{23} \text{M} = 1 \text{g}

1000 \text{g} = 1 \text{kg}

6 \times 10^{27} \text{g} = 1 \text{e}

\frac{1}{21} \underline{L} = 1 \text{cm}

1 \underline{L} = 21 \times 10^8 \text{Å}

10^2 \underline{cm} = 1 \text{m}

1000 \underline{m} = 1 \text{km}
## Voyager Golden Record

© FRANK DRAKE

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>139 x 10^4</td>
<td>4840</td>
</tr>
<tr>
<td>58 x 10^6</td>
<td>108</td>
</tr>
<tr>
<td>333000</td>
<td>82</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period (days)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>243</td>
<td>1</td>
</tr>
</tbody>
</table>

Solar System Definition (part 1)
## Voyager Golden Record

© FRANK DRAKE

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>142 x 10³</td>
<td>121 x 10³</td>
</tr>
<tr>
<td>778 x 10⁶</td>
<td>1428</td>
</tr>
<tr>
<td>318 e</td>
<td>95</td>
</tr>
<tr>
<td>41/100 d</td>
<td>43/100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inside</th>
<th>Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>47600</td>
<td>44600</td>
</tr>
<tr>
<td>2872</td>
<td>4498</td>
</tr>
<tr>
<td>14 6/10</td>
<td>17 2/10</td>
</tr>
<tr>
<td>45/100</td>
<td>65/100</td>
</tr>
<tr>
<td>9/10</td>
<td>7/10</td>
</tr>
</tbody>
</table>

**Solar System Definition (part 2, poor pluto)**
Voyager Golden Record

Spectrum of our Sun (a G0V dwarf)
Are there other Advanced Civilizations in the Galaxy?

Frank Drake worked on this problem. He founded SETI (Search for Extraterrestrial life).

In 1972, with Carl Sagan, he designed the Pioneer Plaques, a pair of gold anodized aluminum plaques placed on the Pioneer 10 and 11 spacecraft launched by NASA in 1972 and 1973. (Also worked on “golden records” carried by Voyagers.)

Pioneer 10 and 11 were the first human built objects to leave the solar system. Each carries a plaque attached to the antenna support strut (shielded from stellar dust).

In 1974, he wrote a radio message broadcast from the Arecibo Telescope to the globular star cluster M13.
How to decipher the message

Original 1974 message

Showing decimal numbers 1-10

Atomic Numbers for
1 = Hydrogen  8 = Oxygen
6 = Carbon      15 = Phosphorus
7 = Nitrogen

Formulas for Sugars and Bases in Nucleotides of DNA

Number of Nucleotides in DNA

DNA Double Helix

Height of Human
= 144 * 12.6 cm = 176.4 cm = approx 5'9"

Population of Earth

The Solar System
(highlighting the third planet)

The Arecibo Telescope

Diameter of telescope
(2.430 wavelength units)
<table>
<thead>
<tr>
<th>Height of Human</th>
<th>Height of Helix</th>
<th>Population of Earth</th>
<th>Number of Nucleotides in DNA</th>
<th>Formulas for Sugars and Bases in Nucleotides of DNA</th>
<th>Atomic Numbers for Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>134.26 cm</td>
<td>142.6 cm</td>
<td>176.4 cm</td>
<td>15.6</td>
<td>1 = Hydrogen, 2 = Oxygen, 8 = Oxygen, 9 = Carbon, 15 = Phosphorus</td>
<td></td>
</tr>
</tbody>
</table>

Showing decimal numbers 1-10.

Formulas for Sugars and Bases in Nucleotides of DNA:
- 1 = Hydrogen
- 6 = Carbon
- 7 = Nitrogen
- 8 = Oxygen
- 9 = Carbon

**Formulas for Sugars and Bases in Nucleotides of DNA:**
How to decipher the message

Original 1974 message

10 9 8 7 6 5 4 3 2 1

Showing decimal.

Atomic Numbers:
1 = Hydrogen
6 = Carbon
7 = Nitrogen

Formulas for Sugars and Bases in Nucleotides of DNA

Number of Nucleotides in DNA

DNA Double Helix

Human

Height of Human
= 14'12.6" cm = 176.4 cm = approx 5'9"

Population of Earth

The Solar System
(highlighting the third planet)

The Arecibo Telescope

Diameter of telescope
(2.430 wavelength units)
How many Advanced Civilizations are there in the Galaxy?
How many Advanced Civilizations are there in the Galaxy?

In 1960 Frank Drake estimated the number of Civilizations, $N$, with whom we might make contact:

$$N = R^* \times f_p \times n_e \times f_\ell \times f_i \times f_c \times L$$

- $R^*$ = average rate of forming stars in the Galaxy
- $f_p$ = fraction of stars with planets
- $n_e$ = number of Earth-like planets per solar system
- $f_\ell$ = average of Earth-like planets that develop life
- $f_i$ = average fraction of life-bearing planets which have (at least) one intelligent species
- $f_c$ = average fraction of intelligence-bearing planets capable of interstellar communication
- $L$ = average lifetime of a civilization to remain technologically advanced
What are plausible values for the Drake equation?

http://www.youtube.com/watch?v=0Ztl8CG3Sys

(alternate link:)

http://www.youtube.com/watch?v=RB_v99FSTYc
Now we are finding that “most” (many, at least) other stars have planets...

http://www.kqed.org/quest/television/the-planet-hunters
If the Universe is teaming with Aliens, where are they?! 

Fermi’s Paradox

- Plausible arguments suggest that civilizations should be common.
- Most should be tens of thousands to a billion years ahead of us technologically.
- So, where are they?
If the Universe is teaming with Aliens,
where are they ?!

1. Maybe we are alone....

2. Intelligent civilizations are common, but interstellar travel is not possible.

3. There is a Galactic civilization, but they haven’t been interested in us (we’ve only had radio for ~70 yrs, rudimentary spaceships for ~50 yrs).
Are aliens out there?
Experiments like “SETI” look for signals.
Where is the Intelligent Life in the Galaxy?

http://www.kqed.org/quest/television/seti-the-new-search-for-et
Your computer can help process the SETI signals (in case it’s not as strong as in Contact....
Are aliens talking to us?

How would we communicate?
We would have mathematics, physics, and chemistry in common.

http://www.youtube.com/watch?v=kNAUR7NQCLA

Go watch the movie Contact, based on the book by the late astronomer, Carl Sagan:

http://www.youtube.com/watch?v=TmSYXbgcozY
The Anthropic Principle

We live in a Universe in which the conditions are favorable for the development of intelligent life.

In 1961, Robert Dicke noted that the age of the Universe as seen by living creatures can not be random.

If the Universe were 10% of its present age (1.4 billion years), there would not be time for appreciable metals to have fused in stars (especially Carbon, Oxygen, Nitrogen). Thus no (intelligent) life made from such stuff.

If the Universe were 10 times older than now (140 billion years), most stars would be too old to remain on the main sequence and would have turned to white dwarfs. Thus, no (intelligent) life?
The Anthropic Principle

Worse still, consider the fundamental physical constants. For example:

---

If the Gravitational Constant, $G$, were slightly higher:

1. Stars would burn hotter, and their lifetimes would be much less than the time it takes for life to evolve to “self-awareness”.

2. The Expansion of the Universe may have stopped long ago and the Universe collapsed to the “big crunch”.

---

If the Gravitational Constant, $G$, were slightly weaker:

Hydrogen clouds might never fragment to form stars and fuse Carbon, Oxygen, etc, etc. Even if stars do form, gravity will not be strong enough to generate the heat/pressure in stars to fuse Heavy elements that make up life.
The Anthropic Principle

Weak Anthropic Principle refers to the fact that we live during a privileged time in the Universe.

Strong Anthropic Principle refers to the controversy that the physical constants all seem “finely tuned” to support the development of intelligent life.
The Anthropic Principle

Roger Penrose described it this way:

"The argument can be used to explain why the conditions happen to be just right for the existence of (intelligent) life on the earth at the present time. For if they were not just right, then we should not have found ourselves to be here now, but somewhere else, at some other appropriate time. ... 

The issue concerned various striking numerical relations that are observed to hold between the physical constants (the gravitational constant, the mass of the proton, the age of the universe, etc.).

A puzzling aspect of this was that some of the relations hold only at the present epoch in the earth's history, so we appear, coincidentally, to be living at a very special time (give or take a few million years!). This was later explained...by the fact that this epoch coincided with the lifetime of what are called main-sequence stars, such as the sun. At any other epoch...there would be no intelligent life around in order to measure the physical constants in question-so the coincidence had to hold, simply because there would be intelligent life around only at the particular time that the coincidence did hold!"

— The Emperor's New Mind, Chapter 10