*Life in the Universe Experiment A11*

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| Name |  | Lab Section |

*Objective*

* Part A – Probability
* Part B – The Drake Equation
* Part C – The Fermi Paradox

*Materials*

2 Dice Computer with Internet Access

*Theory*

The “holy grail” in all of astronomy is to find life somewhere other than Earth. In short, “extraterrestrial life” or “aliens.” Currently, we have no definitive proof of life that has originated outside of Earth. Life on our planet, as far as we know, is the only life in the Universe.

However, it is likely there is life outside of Earth. Consider how many stars are in our home galaxy, the Milky Way. There are an estimated 200-400 billion stars. Over the last few decades, observational evidence estimates that each star has, on average, 1.6 planets. Our solar system has more than average with our 8 planets, which means others will have none, but on average data suggests there are 1.6 planets per star throughout the galaxy.

This means roughly there are about 300-600 billion planets for life to form. (We’re also learning moons might also have ideal conditions where life could thrive, which could increase that number even further. Possible over a trillion places through the galaxy for life to start.) Now, not every planet is suitable for life. Some will be too far from their star and freeze. Some will be to close and bake in the intense heat.

There are still a lot of places for life to begin, and the Milky Way is an estimated 12 billion years old, which gives a lot of time for life to have begun and evolve. Our goal in this experiment is to think about the conditions for life, the probability that it’s somewhere else in the galaxy, and to consider the paradox of the numerous opportunities for life but the lack of evidence alien life is out there.

*Procedure*

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| ***Part A: Probability*** |

As a warmup exercise, we will roll dice as a way to understand probability. Dice are a good, simple way to think about probabilities. If you don’t have dice you can roll yourself, [online dice simulators can be found here.](https://www.random.org/dice/)

***Probability in Dice***

1. What is the possibility of getting a “4” with a single roll of a die?

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1. Roll a single die sixty times and keep track of the number you get in each roll. How many times did you get the number “4”?

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1. If you roll one die, six hundred times, approximately how many times would you *expect* to get a “4”? What if you rolled the die six thousand times? What is the significance of rolling the die *many* times?

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1. Write your own definition of “probability”. Explain the meaning of a probability of 0, ½, and 1. Why can the rules of probability be applied to dice rolling.

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***Compound Probabilities – Multiple Events (Rolling Two Die in a Row)***

1. If you have two dice, what is the probability of rolling a “4” on the first die followed by a “2” with the second die?

*Hint:* Write down all the possible two-number outcomes that you could obtain.

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***Playing the Lottery***

1. Imagine you are playing a “Pick-3” type lottery game. Three numbers are drawn, each ranging from 0-9 (numbers can be repeated). To win the largest prize, you must match all three numbers in the exact order in which they are drawn.

If you buy one ticket, what are you chances of winning the top prize? Explain your reasoning and show any calculations.

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***Real World Estimates***

1. Estimate the *total number of carpeted rooms* in the households of *all students* in the astronomy lab right now. Don’t expect to go around asking your classmates how many carpeted rooms they have. This is a guessing game using logic. Express your estimate in the form of an equation. For example,

where *N* is your estimate for the number of carpeted roomsand *a, b, c, etc.* are the quantities that you are using to arrive at your estimate. You may choose your own variables to represent each part of your equation; make sure you *state what each variable represents!*

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1. What are the most uncertain factors in your estimate? How could you improve your estimate?

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| ***Part B: The Drake Equation*** |

The Drake equation is a probabilistic argument (just like your previous estimate on carpeted rooms) that is used to estimate the number of active, communicative extraterrestrial civilizations in the Milky Way galaxy. The equation was written in 1961 by Frank Drake not for purposes of quantifying the number of civilizations but intended as a way to stimulate scientific dialogue at the world's first *Search for ExtraTerrestrial Intelligence* (SETI) meeting, in Green Bank, West Virginia. The equation summarizes the main concepts which scientists must contemplate when considering the question of other alien civilizations. The Drake equation has proved controversial since several of its factors are currently unknown and estimates of their values span a very wide range.

The Drake equation is as follows:

where *N* is the estimate of the number of alien civilizations in the Milky Way Galaxy that are currently able to communicate with humans.

A good explanation of Drake’s equation can be found in this YouTube video:

<https://www.youtube.com/watch?v=80Ryq6bH2aY>

1. Watch the video, or look up online, and write in your own words what each variable in the Drake Equation represents:

*N* :

*R\** :

*fp* :

*ne* :

*fl* :

*fi* :

*fc* :

*L* :

1. Visit the website <http://www.pbs.org/lifebeyondearth/listening/drake.html>.

This website is a calculator that will estimate the number of intelligible civilizations in the Milky Way. Guess some of the values for the variables in the Drake Equation and use the website to calculate the number of civilizations we can expect to find in the Milky Way.

Number of Civilizations:

1. Now use the *More* button after each explanation on the website and use the current best values given there to estimate the number of civilizations.

Current Best Estimates on the Number of Civilizations:

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| ***Part C: The Fermi Paradox*** |

The Fermi paradox (or Fermi's paradox) is the apparent contradiction between high estimates of the probability of the existence of extraterrestrial civilization and humanity's lack of contact with, or evidence for, such civilizations. The basic points of the argument, made by physicists Enrico Fermi and Michael H. Hart, are:

* The Sun is a typical star, and relatively young. There are billions of stars in the galaxy that are billions of years older.
* Almost surely, some of these stars will have Earth-like planets. Assuming the Earth is typical, some of these planets may develop intelligent life.
* Some of these civilizations may develop interstellar travel, a technology Earth is investigating even now (such as the 100 Year Starship).
* Even at the slow pace of currently envisioned interstellar travel, the galaxy can be completely colonized in a few tens of millions of years.

According to this line of thinking, the Earth should already have been colonized, or at least visited. But no convincing evidence of this exists. Furthermore, no confirmed signs of intelligence have yet been spotted in our galaxy or elsewhere in the observable universe. Hence Fermi's question, "Where is everybody?"

There are a number of logical arguments to the question “Where is everybody?” Among them are:

1. We are alone. We are the only civilization in the Milky Way or possibly even the Universe.
2. There is other life in the galaxy but no advanced civilizations capable of communication.
3. Civilizations are common, but for various reasons no one has colonized the galaxy. For example, some arguments state that galactic colonization is too expensive and therefore civilizations would not attempt to do so.
4. Aliens were here in the past or are currently here hiding among us.
5. We are the aliens of a past civilizations.
6. Aliens do not contact us to allow us to develop and evolve naturally (aka - The Zoo Hypothesis).

Kurzgesagt has a phenomenal video about the Fermi Paradox:

<https://www.youtube.com/watch?v=sNhhvQGsMEc>

From the reasons above, or one of your own, or a combination of several reasons, discuss with your group write your argument for why we have not made contact with any alien civilizations. Be thorough in your argument, give examples, provide resources, and give facts or numbers when possible. Even if your argument is that we are alone, thoroughly explain why. Consider this a debate and you need good, well-formed arguments to get others to agree with you.

*(This section is the most important in this experiment. To earn full points your argument must be logical, well thought out, and supported by evidence. It’s okay to think there are no other alien civilizations. However, you must still support your argument with facts. Be thorough!)*

***Your argument:***

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| Enter Answer Here |

*This lab manual was written by Justin Mason, Old Dominion University, and copied to be made available on this website by Corey Sargent, Old Dominion University, Fall 2021*