In 1961, astronomer Frank Drake devised an ingenious equation that has helped generations of scientists estimate how many intelligent civilizations may exist in the Milky Way. The 'Drake Equation' looks like this:

N = S x P x E x C x I x A x L

Where:

S = Number of stars in the Milky Way

P = Fraction of stars with planets

E = Number of planets per star in the right temperature zone

C = Fraction of planets in E actually able to support life

I = Fraction of planets in C where intelligent life evolves

A = Fraction of planets in I that communicate with radio wave technology

L = Fraction of a stars lifetime when communicating civilization exists

On Earth, bacteria have existed for nearly 4 billion years. Insects for 500 million years. Modern humans for 20,000 years. Which lifeform is the most likely to be found on a distant planet?

Known values:
S = 500 billion
P = 0.1

For our solar system:
E = 2 (Earth and Mars)
C = 0.5 (Earth)
I = 1.0 (Earth)
A = 1.0 (Earth)
L = 0.00000002 (100 yrs/4.5 billion yrs)

The great challenge is to determine from direct or indirect measurements what each of these factors might be. Fortunately, there are at least a few of these factors that we have pretty good ideas about, especially for our own planet. The estimate based on the solar system as a model is the sum of the products in the sample table N = 500 billion x 0.1 x 2 x 0.5 x 1.0 x 1.0 x 0.00000002 = 1000 civilizations existing right now.

Question 1: Based on your internet research, what do you think are the possible ranges for the factors P, E, and C? Remember to cite your sources and use only primary sources by astronomers or other scientists, not opinions by non-scientists.

Question 2: Which factors are the most uncertain and why?

Question 3: What kinds of astronomical observations might help decide what the values for E and C?

Question 4: Using the evolution of life on Earth as a guide, what could you conclude about I? What is the most likely form of life in the Milky Way?

Question 5: How would you try to estimate A using a radio telescope?

Question 6: What would the situation have to be for the value of L to be 0.000002 or 0.000000002?

Question 7: Using the Drake Equation, and a Milky Way in which 1 million intelligent civilizations exist, work backwards to create a 'typical' scenario for each factor so that a) N = 1 million. B) N = 1. Make sure you can defend your choices of the different factors.

Question 1: Based on your internet research, what do you think are the possible ranges for the factors P, E, and C?

Answer: Students may cite the following approximate ranges, or plausible variations after providing the appropriate bibliographic reference: P probably between 1% and 10% based on local planet surveys; E between 1 and 3 based on planet surveys and our own solar system; C between 0.1 and 0.5;

Question 2: Which factors are the most uncertain and why?

Answer: I , A and L. These depend on the details of evolution on non-Earth planets and it is basically anyone's guess what these numbers might be. Students may consult various internet resources or essays on the Drake Equation to get an idea of what ranges are the most talked about.

Question 3: What kinds of astronomical observations might help decide what the values for E and C?
Answer: Our best tool is to conduct surveys of nearby stars and attempt to detect earth-sized planets, not the much larger Jupiter-sized bodies that astronomers currently study.

Question 4: Using the evolution of life on Earth as a guide, what could you conclude about I? What is the most likely form of life in the Milky Way?

Answer: Bacteria were the first life forms on Earth and have survived for nearly 4 billion years. Statistically, they should be the most common life forms in the universe. Also, alien life forms are much more likely to be simple rather than complex. This is favored by the distribution of life on Earth, in which there are very few complex organisms compared to simple ones, especially if you rank them by the total mass of the species and use this to set probabilities. For example, for every billion pounds of bacteria, there are perhaps only 1 thousand pounds of species larger and more complex than insects.

Question 5: How would you try to estimate A using a radio telescope?

Answer, by measuring the radio output of thousands of stars every year and looking for signs of intelligent 'modulation' like a morse-code signal. Stars don't normally emit radio signals that vary in a precise way in time. The SETI program is continuing to conduct these kinds of surveys.

Question 6: What would the situation have to be for the value of L to be 0.000002 or 0.000000002?
Answer: A star like the sun lives for about 10 billion years. L would then be 10 billion x 0.000002 = 20,000 years or as little as 10 billion x 0.000000002 = 20 years. In the first case, a civilization has learned to survive its technological 'Childhood' and prosper. In the second case, the civilization may have perished after learning how to use radio technology, or it may still be a thriving civilization that no longer uses radio communication.

Question 7: Using the Drake Equation, and a Milky Way in which 1 million intelligent civilizations exist, work backwards to create a 'typical' scenario for each factor so that a) N = 1 million. B) N = 1.

Answer: This will depend on the values that students assign to the various factors. Make sure that each student can defend their choice. This may also be opened to class discussion as a wrap-up.