Lesson #1:
Introduction to the Drake Equation Terms: "Anyone Out There?"

Lesson Summary

- **Grade level:** 6th -12th
- **Prep time:** ~10 minutes (if a tour of the TED ED website is needed for the teacher only; otherwise, no preparation needed.
- **Lesson time:** 45 minutes for presentation and discussion and ~40 minutes total for activity. Two optional accompanying activities take 10 minutes and ~3 hours (at-home assignment) or shorter class discussion.
- **Learning outcomes**: Goals of the introductory lessons are to introduce the Drake equation and Fermi paradox to students and to "set the stage" for the rest of the lesson package.

Benchmarks For Science Literacy (from the American Association for the Advancement of Science) addressed:

Grades 6-8:

- ✓ Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested against observations.
- ✓ What people expect to observe often affects what they actually do observe. Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results.
- ✓ Scientists know about the danger of prior expectations to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions.

Grades 9-12:

- ✓ In matters that can be investigated in a scientific way, evidence for the value of a scientific approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.
- ✓ Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but scientists want to know the possible sources of bias and how bias is likely to influence evidence.

What students do

The goals of this lesson is to give students an overview about the science of what astrobiology is, is not, and the many misconceptions associated with life in the universe. This lesson will shed light onto the multidisciplinary way that astrobiologists approach the question, "Are we alone?" and introduces a way to rationalize why we do not have an answer to this question yet.

This lesson will also introduce the Drake equation, which organizes astrobiologists' thinking about this question into a set of seven factors that provide a relevant way of estimating the number of intelligent civilizations in our Milky Way Galaxy. Without this lesson, the rest of the lesson package will not be easily implemented. This lesson is the foundational starting point for the other seven. Each subsequent lesson will be an in-depth look at one Drake equation term and will examine the science of that term with at least one enrichment activity provided for teachers per term.

This lesson introduces the others, each aligning with many science standards of the Next Generation Science Standards and Scientific and Engineering Practices, Crosscutting Concepts, and Scientific and Engineering Practices.

At the end of this lesson, students will be able to:

✓ **Recall** main ideas about the Kepler Mission and its relevance to astrobiology, the Fermi paradox, the Drake Equation, and about SETI

✓ **Recognize** how 3 main innovations will fuel the search for life and what other forms of life astrobiologists are looking for, and why the Drake equation is useful as an equation without an answer

✓ **Illustrate and imagine** a scenario for an advanced life form

✓ **Construct** a valid argument around the search-for-life paradox surrounding our planet's formation relative to that of the universe and by constructing an argument about a possible "answer" to "are we alone?"

The following Next Generation Science Standards will be addressed in this lesson:

Scientific and Engineering Practices:

Engaging in argument from evidence;
Obtaining, evaluating, and communicating information;

Resources needed:

- **Accompanying Intro to Drake Equation PowerPoint** © NASA Night Sky Network

  (System requirement: Microsoft Office)

- **Script for PowerPoint:**

  Available in the notes section of each slide and also separately ("DrakeEqn ppt script and lesson notes for teachers.ppt.") NOTE on script document: The NASA Night Sky Network refers to the R* Drake Term as "N*" so do not get confused. "N*" has been changed in the editable PowerPoint to show students but it cannot be edited in the PDF. To avoid confusion, teachers should call this term and the accompanying lesson "R*". It is more common to use this name.

- **Classroom (or computer lab) with student access to:**

  - **http://ed.ted.com**
  - **Optional: YouTube.com** for introductory videos to pop-culture songs on what astrobiology means if you are able to access YouTube in your class.

Copyright/permission statement

Science of the Topic

1. Read the following:

In popular culture, we imagine a universe full of intelligent alien life from planets orbiting other stars. We also imagine that they are already here. What examples can you give of this?

Teacher's Tip: Students will say UFOs and will cite popular movies dealing with good- or evil- intentioned aliens. Some may even evoke the idea of "ancient aliens" who were thought to have helped early civilizations like the Egyptians develop their pyramids. Of course, all of these are popular culture examples not rooted in facts. Teachers may spend as little or as much time with these ideas as they wish.

But, let's approach this scientifically, not mystically, using real scientific reasoning. How do scientists think about where the aliens are and why we don't have any real, definitive proof of their visiting us? Here is a story to introduce the Drake Equation.

On the way to lunch one day in 1950, a scientist named Enrico Fermi (1901-1954) and some colleagues discussed UFOs. What are the chances that we might observe evidence of advanced intelligence, they wondered?

During lunch, Fermi was said to exclaim "where is everybody?" after making some simple calculations. He had determined that Earth could have been visited many times over. Let's examine this question and why it's called a paradox.

2. Play the "Intro lesson and Drake Eqn copyright NASA Night Sky Network.ppt" for students. This will clarify the concepts of astrobiology and the Drake Equation, as well as prepare students for each following Drake Term lesson.

Teacher's Tip: A script is available in the notes section of each slide and also separately as "DrakeEqn ppt script and lesson notes for teachers.ppt. Notify Svetlana if you need this file.

Vocabulary list

Students can be given the following terms to define as a take-home or class discussion assignment at any part of this lesson which the teacher feels is appropriate, or just to have while doing the lesson for reference. Online sources for these definitions are provided at the end of each and students or teachers may wish to explore these sites further. If assigning these words for students to define, a print out sheet follows. Note that students or teachers can add to this along the way during the introductory lesson. Note that each following lesson will have its own list of vocabulary.

1. **Drake Equation** –

How can we estimate the number of technological civilizations that might exist among the stars? While working as a radio astronomer, Dr. Frank Drake conceived an approach to bind the terms involved in estimating the number of technological civilizations that may exist in our galaxy. The Drake Equation, as it has become known, identifies specific factors thought to play a role in the development of such civilizations. Although there is no unique solution to this equation, it is a generally accepted tool used by the scientific community to examine these factors (www.seti.org).

2. **Astrobiology** -

Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe. This multidisciplinary field encompasses the search for habitable environments in our Solar System and habitable planets outside our Solar System, the search for evidence of prebiotic chemistry and life on Mars and other bodies in our Solar System, laboratory and field research into the origins and early evolution of life on Earth, and studies of the potential for life to adapt to challenges on Earth and in space.

NASA's Astrobiology Program addresses three fundamental questions: How does life begin and evolve? Is there life beyond Earth and, if so, how can we detect it? What is the future of life on Earth and in the universe? In striving to answer these questions and improve understanding of biological, planetary, and cosmic phenomena and relationships among them, experts in astronomy and astrophysics, Earth and planetary sciences, microbiology and evolutionary biology, and other relevant disciplines are participating in astrobiology research and helping to advance the enterprise of space exploration (www.astrobiology.nasa.gov).

3. **Fermi's Paradox** -

The Fermi Paradox is the apparent contradiction between the high probability extraterrestrial civilizations' existence and the lack of contact with such civilizations (http://www.seti.org/seti-institute/project/details/fermi-paradox).

Vocabulary list

Name: _____
Due: _____

1. Drake Equation –

2. Astrobiology -

3. Fermi's Paradox -

Activity 1: Watch short videos about the Fermi Paradox and answer questions

Time: ~1 hour or less (Two 6 minute videos with discussion and questions)

Level: 6th -12th

Standard with which it aligns:

Scientific and Engineering Practices:
Obtaining, evaluating, and communicating information

About this activity: Students will watch one or both short videos and complete about 10 multiple choice questions accompanying it at the end as a group activity.

Learning Outcomes:

The following taxonomy for learning is adapted from Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process. According to these outcomes, after this activity, students will:

1. **Remember facts about the Drake Equation, SETI, Fermi Paradox, and the NASA Kepler Mission**

    1.1 By recalling main ideas about the Kepler Mission and its relevance to astrobiology, the Fermi paradox, the Drake Equation, and about SETI

    1.2 By recognizing how 3 main innovations will fuel the search for life and what other forms of life astrobiologists are looking for, and why the Drake equation is useful as an equation without an answer

2. Understand real possibilities for advanced life forms

    2.2 By exemplifying through illustrating and imagining a scenario for an advanced life form

6. Create a sound argument from facts:

    6.3 By Constructing a valid argument around the search-for-life paradox surrounding our planet's formation relative to that of the universe and by constructing an argument about which "answer" to the "are we alone" question the student prefers

Preparation:

Before beginning, teachers can watch the online video tour to learn about this educational website and its organizers. This link, http://ed.ted.com/tour, provides an overview in several forms of the purpose and organization of this educational video lesson website designed for the middle and high school level.

In the classroom, teachers should show the following two TED ED videos:

1. **Why Can't we See Evidence For Alien Life?**
   Link: http://ed.ted.com/lessons/why-can-t-we-see-evidence-of-alien-life

Teacher's Tip: Students may bring up questions about God and budget issues that could account for why we can't see evidence of aliens. Please see Misconceptions section at the end of this lesson for suggestions on how to deal with such questions.

2. **Calculating The Odds of Intelligent Alien Life**
   Link: http://ed.ted.com/lessons/calculating-the-odds-of-intelligent-alien-life

Directions:

1. Group the students into several groups (recommended: 3-5 students per group).
2. Watch the first video.
3. Click on "Think" and go through the multiple choice and short answer questions with students by assigning one question to each group to answer to the class after a 1 minute consultation.

Teacher's Tip #1: Multiple questions can be assigned per group if there are not enough groups. For short answer questions, teachers should ask groups to come up with a consensus argument or conclusion after 5 minute group consultation. Teacher may wish to assign positions or conclusions to different groups or to different locations in the classroom and have students pick to join the group which is assigned the position which they favor. Students may regroup between questions or at any point, especially if teachers allow them to self-select to go into groups assigned their favorite position from one short answer question to the next.

Teacher's Tip #2: Teachers can show the two videos together and do both sets of "Think" questions at once, or show one video, do the "Think" questions for that video, and then show the other. Teachers may even wish to show the two videos in separate class sessions, but is recommended that teachers do not skip either video. If pressed for time, teachers may wish to just show videos without answering the accompanying "Think" questions.

Teacher's Tip #3: If desired, encourage students to do the "Dig Deeper" activities discussion, or project assignments, or as something optional for enrichment.

Assessment

Teachers should grade this by allowing students to go through the questions in the "Think" portion after each video and self-reporting the ones they answered correctly. Note that long answers cannot be graded automatically on the website but should instead be assessed as classroom focus group discussions. Note that each question has a "Check My Answer" feature that can be clicked. This is what students should use to self-grade themselves. Note: this method of assessment is subject to student interpretation but it is a fast and appropriate way to grade such an assignment with the help of the automatic grading feature.

Alternately: Teachers can use the questions in the Think and Dig Deeper portions of the website after each video to guide the creation of a quiz or fill-out worksheet which the students can do without a computer after watching the videos. This way, teachers can grade the short answer portions which the students submit.

Optional Activity: Further reading and Homework assignment: Read a book chapter and construct an essay

Time: Recommended ~1-3 hours for student completion at home over the course of one evening or week. A longer time is recommended if this is an independent research project.

Level: 9th -12th

Standards with which it aligns:

Scientific and Engineering Practices:

Engaging in argument from evidence; and
Obtaining, evaluating, and communicating information;

Learning outcomes

The following taxonomy for learning is adapted from Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process. According to these outcomes, after this activity, students will:

5.2 Critique erroneous conclusions about answers to the Fermi paradox

About this activity:
If teachers are able to get a hold of chapter 1: "Is Anybody Out There?" from Paul Davies' book, The Eerie Silence: Are we Alone in the Universe and copy it for students or find the chapter online, then they can distribute it to students. Students write an essay of 1 page with an answer to each question below.

Teachers should also hand out rubric that follows the assignment page to guide students in the effort which they put into this assignment.

If doing this as a homework essay, the following page should be handed out to students. It is recommended that students hand this in as a hand-written assignment to discourage copying text off of the web. Teachers can assign a due date and have students fill it in on the sheet that follows. Alternatively, this can be a class discussion rather than an essay.

Assessment

Teachers should expect students to answer giving some variation of one of the following interpretations with support which they make up themselves or find using outside research, if that is possible: (1) We are alone. (2) We are looking in the wrong place at the wrong time and with the wrong technologies. A grading rubric follows this worksheet.

Teacher's Tip: The "Misconceptions about Life in the Universe and UFOs" document following this assignment and the rubric also provides answers to this assignment. If handing out that sheet (which is encouraged), do so after students hand in this assignment.

Teacher's Tip: Teachers can tell students that the last term of the Drake equation will explore this latter idea further.

An Exploration of Fermi's Paradox: So Where Are the Aliens?

Name: _____
Due: _____

Instructions:
Read P. Davies, The Erie Silence: Are we Alone in the Universe, Ch. 1: Is Anybody Out There?

Write an essay of 1 page with an answer to the question below.

What were the incorrect conclusions that can be made about why we have not proven extraterrestrial life exists yet? Choose one and explain why it is erroneous. Provide TWO (2) pieces of supporting evidence for your claim from the reading or outside sources. You should write an organized, concise essay that clearly introduces your argument, supports it, and then concludes your essay. You are encouraged to use outside research materials for your evidence explanation.

Rubric For Scoring essay, "An Exploration of Fermi's Paradox: So Where Are the Aliens?"

Grade	Criteria Fulfilled to evaluate an erroneous claim
Expert	• Student effectively engaged in argument from evidence • Student effectively obtained and evaluated information • Student effectively communicated information • Student effectively critiqued incorrect conclusions about answers to the Fermi paradox
Proficient	• Student mostly engaged in argument from evidence • Student mostly obtained and evaluated information • Student mostly communicated information • Student mostly critiqued incorrect conclusions about answers to the Fermi paradox
Intermediate	• Student somewhat engaged in argument from evidence • Student somewhat obtained and evaluated information • Student somewhat communicated information • Student somewhat critiqued incorrect conclusions about answers to the Fermi paradox .
Novice	• Student attempted but did not effectively engage in argument from evidence • Student attempted but did not effectively obtain and evaluated information • Student attempted but did not effectively communicate information • Student attempted but did not effectively critique incorrect conclusions about answers to the Fermi paradox

Special Feature: Misconceptions about Life in the Universe and UFOs

In the above essay assignment or any other discussion surrounding life in the universe, in this lesson or any of the others in this 8-lesson package, the following misconceptions may or may not come up. Here are some common misconceptions and suggested ways to address them and think about them like an astrobiologist. The below list is intended to aid teachers in times when questions are brought up and it is unclear what should be replied to stay neutral, unbiased, scientific, and above all, accurate, when discussing these topics which do not have a "wrong" or "right" answer in science. Science standards and Benchmarks addressed are below. This file is provided as a stand-alone document following this instructions section if teachers wish to print copies to distribute to students, which is encouraged.

Teacher's Tip: If doing the P. Davies book chapter assignment, distribute this sheet to students after they hand in their essays. This misconceptions feature addresses some of the points students may write about in their essays.

Teacher's Tip #2: If questions about NASA budgets and religion arise, teachers should answer them at their discretion. Neither this lesson nor any other in this package interferes with any religion or belief system. Please email Svetlana if specific questions arise that the teacher is uncomfortable answering. Tell students you will research an answer and get back to them.

Level: 6th-8th and 9th -12th

Time: N/A

The following Next Generation Science Standards will be addressed in this lesson:

Scientific and Engineering Practices:
Engaging in argument from evidence

Benchmarks addressed:

<u>The Scientific Worldview</u>:

Grades 6-8:

- ✓ Some matters cannot be examined usefully in a scientific way. Among them are matters that by their nature cannot be tested against observations.
- ✓ What people expect to observe often affects what they actually do observe.

Strong beliefs about what should happen in particular circumstances can prevent them from detecting other results.

- ✓ Scientists know about the danger of prior expectations to objectivity and take steps to try and avoid it when designing investigations and examining data. One safeguard is to have different investigators conduct independent studies of the same questions.

Grades 9-12:

- ✓ In matters that can be investigated in a scientific way, evidence for the value of a scientific approach is given by the improving ability of scientists to offer reliable explanations and make accurate predictions.
- ✓ Bias attributable to the investigator, the sample, the method, or the instrument may not be completely avoidable in every instance, but scientists want to know the possible sources of bias and how bias is likely to influence evidence

Why Aren't UFO Reports True?

Misconception 1: There is an answer to the Drake Equation.

Truth: There are too many unknowns, such as the F_c and L Drake Equation terms, for example. There will not be a right answer until either we find evidence of intelligent life definitively or we find evidence of the opposite, definitively, that we are alone in the universe. There is no clear and easy way for scientists to prove the latter. The famous astronomer Carl Sagan wrote, "absence of evidence is not evidence of absence." When will we know if we have looked hard enough? This is perhaps the biggest answer to the Fermi Paradox. As you can see, science isn't a process of right and wrong answers but a journey to understand our place in the grand universe which we inhabit.

There are many assumptions that are made when discussing the Paradox. Here are some of the solutions:

•Lifetimes of civilizations are too short for them to have visited us

•Advanced civilizations may not choose to explore and colonize

•Advanced civilizations don't survive long enough to colonize

•We are the first in our galaxy

•They were/are already here but we can't prove it

Misconception 2: UFOs are real and aliens have visited us.

There is no scientific proof of an argument and until such proof is found, these are only claims, and claims are not sufficient to prove something to be a fact. To be proven a fact, there must be evidence in the argument. That evidence must conform to the following three Standards for Reasoning from Evidence, adapted from a lesson by A. Anbar at Arizona State University's course called Habitable Worlds:

1. **Falsifiability**: For a claim to have the potential to be proven true it must be possible for it to be proven to be false. Otherwise, using evidence to "test" the claim is not really a test at all (just as your passing a test in a class is only meaningful if it was possible for you to fail the test). Other examples of claims that are not falsifiable include predictions of fortune tellers and conspiracy theories. Note that just because a claim cannot be falsified doesn't mean it is not correct. But it does mean that the claim cannot possibly be investigated scientifically.

2. **Logic**: The logic of an argument must be sound. In the UFO business, an example of bad logic is: "Aliens could have been here in flying saucers. Someone saw something that looked like a flying saucer. Therefore, the aliens are here."

3. **Comprehensiveness**: To be valid, an argument needs to be exhaustive, taking into account all the evidence.

Optional Activity: Watching 1-3 Pop Culture Videos to Introduce Astrobiology

Time: ~10 minutes total:

Video 1: 3:24 min.; Video 2: 6:30 min; Video 3: 20 seconds.

Level: 6th-12th grade

About this activity:
Here are 3 fun and funny but **completely optional** pop culture videos to introduce terms, ideas, and set the theme of astrobiology and all of the topics it covers. Students will like the references to popular recent singers (Ke$ha), music styles (rap), and television sitcoms (Big Bang Theory). This is the link to current events and activities and makes the science relatable to students by bringing familiar concepts to them through music and television. Teachers can watch with students and have class discussions. Teachers may want to show these at the beginning of this lesson to set the tone of the science and to introduce the "Are We Alone?" lesson package. The purpose of these videos is to whet the students' appetite and show them that astrobiology and science can be taken out of the classroom in a fun, engaging, (and catchy!) way.

Teacher's Tip: The videos reinforce many of the concepts of the vocabulary terms.

Teacher's Tip: If teachers do not have access to YouTube in the classroom, the first video below does not require it. The other two do.

Teacher's Tip: If teachers choose to skip these 3 videos, this will not take away from the flow or logic of the rest of this or other astrobiology lessons.

1. Ke$ha "We R Who We R" parody - "Astrobiology"

(Can be played via http://www.astrobio.net/video/keha-we-r-who-we-r-parody-astrobiology or downloaded from this site and played offline)

2. Astrobiology Rap! (Requires YouTube Access)

http://www.youtube.com/watch?v=NL3lhm6oy5I

3. Big Bang Theory's Sheldon on the Drake Equation (Requires YouTube Access)

http://www.youtube.com/watch?v=P_E_ZtRZ1yk

Stay tuned for another activity!

Teacher's Tip: In future iterations of this lesson package, which seeks continuing improvement, there are plans to include another activity to introduce scales of the universe, complete with standards, rubric, and all of the other portions of that activity. It will employ a fun interactive online simulator where students can zoom in and out on to common and uncommon micro- and macroscopic objects and appreciate the vast scales of space to the tiny scales of subatomic particles. This aligns with the Next Generation Science standard dealing with scales and proportions. Stay tuned!

Congratulations!

You've completed the Introductory lesson. Next, you will explore with your students the 7 lessons on each of the drake terms, each lesson with an activity one or more standards with which it aligns. Once fully designed, the rest of the lesson package will align with the following cross-disciplinary standards from the document, "A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" written by the National Research Council.

R* Lesson: Formation of Stars
- #PS1-1, 2, 3, and 8: Nuclear processes, chemical reactions, and the atom

f_p Lesson: Stars And Their Planets
- #ESS1.B: Earth and the Solar System

n_e Lesson: Which Planets Are Capable Of Sustaining Life
- #ESS2.C: The Roles of Water in Earth's Surface Processes

f_l Lesson: Why Life Evolves
- #ESS2.C: The Roles of Water in Earth's Surface Processes
- #ESS2.D: Weather and Climate

f_i Lesson: Intelligent Life
- #LS4.A: Evidence of Common Ancestry and Diversity
- #LS4.B: Natural Selection
- #LS4.C: Adaptation
- #LS4.D: Biodiversity and Humans

f_c Lesson: Communicating Civilizations

This lesson is part of the Scientific and Engineering Practices Framework that teaches the *process* of good scientific thinking and methods in the science classroom and in

everyday life, too. This dimension permeates all of the other science standards as a method and goes over crucial, practical skills such as asking questions, defining problems to solve, engaging in argument based on evidence, analyzing and interpreting evidence, and constructing valid explanations based on evidence.

L Lesson: The Lifetime of a Communicating Civilization

#ETS2.B: Influence of engineering, technology, and science on society and the natural world