# The Question of Life

In this, **our last class for PHY111**, we want to take up the question of:

**Astrobiology : The study of life beyond Earth**

**The major difficulty faced by Astrobiologists is: (LC)**

- At the present time, there is nothing to study!
- But, we should remember what Copernicus taught us:

  *The Earth is not a special planet in a special place; neither is the Sun a special star; nor is the Milky Way Galaxy a special galaxy; perhaps we can say the same about life.*

**We shall concentrate on three questions:**

- **What is life, and how do we think that it arose on Earth (. . *if it did*)?**
- **Should we expect to find life elsewhere *(. . or elsewhen*) in our Solar System?**
- **Are there other "Technological" civilizations in the Milky Way galaxy, and can we communicate with them?**

# Life on Earth

**First, what is life?** How do we distinguish between living and nonliving matter?

This is not an easy question to answer; I'm reminded of Supreme Court Justice Potter Stewart's response to how one would define pornography:

***"I can't define it, but I know it when I see it."***

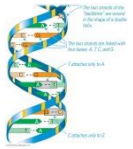
**You author proposes that life on Earth has (to some degree) the following properties:**

| | |
|---|---|
| **Order** | **Reproduction** |
| **Growth & Development** | **Energy Utilization** |
| **Response to Environment** | **Evolutionary Adaptation** |

Note, there are many cases where inanimate matter exhibits one or more of these.

**So we just have to accept that we can't really define life, and take it from there.**

**How would we describe life on Earth?**



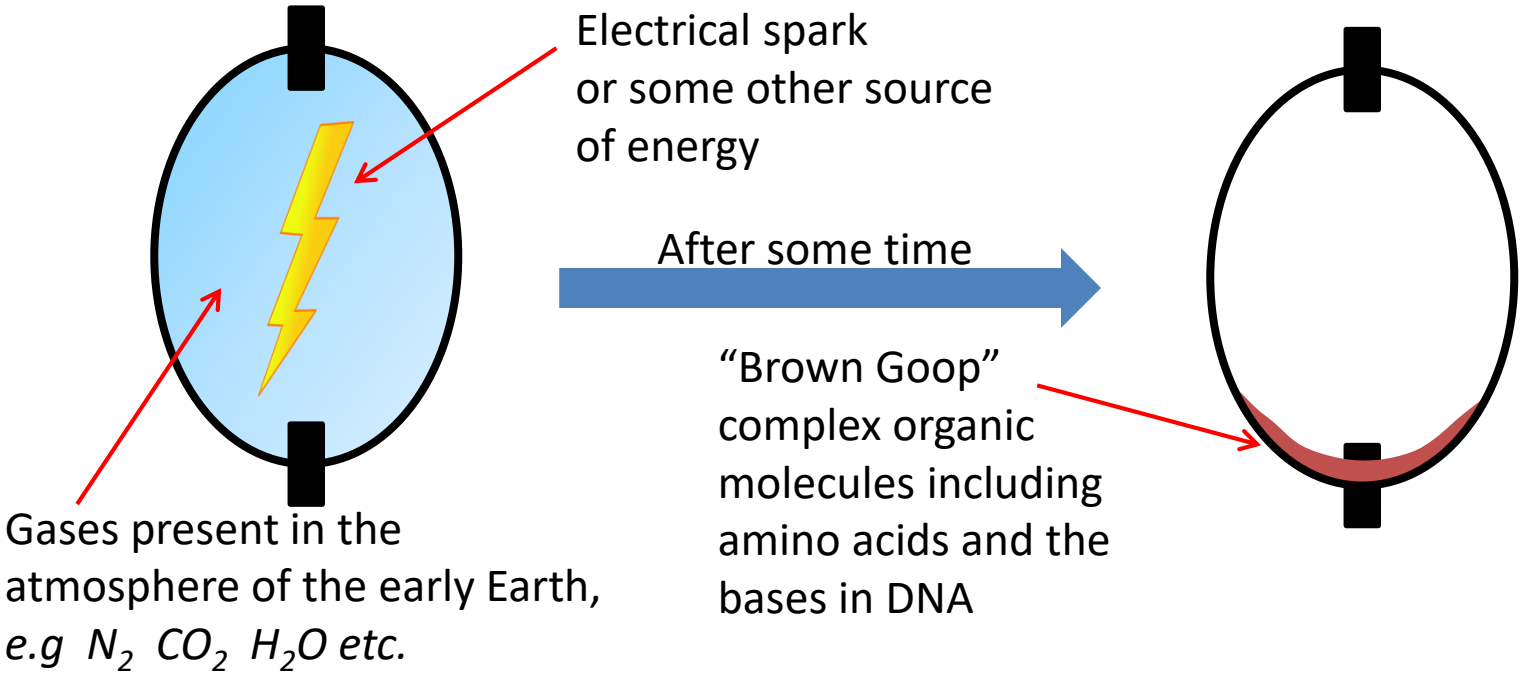
(*we think*) All life on Earth is based on the molecular chemistry of Carbon, which is plentiful in the cosmos (**LC, where does it come from**), and uses the DNA molecule to encode and pass on its characteristics to its descendants.

Of course, many science fiction writers imagine extensions to this form of life, e.g. 

# Life on Earth

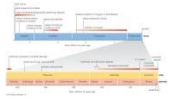
**How did life arise on Earth?** (. . *if it did*)

It is unlikely that we'll ever know the details, but a class of experiments known as the **Miller-Urey Experiments** shows how the necessary chemicals may have formed:




**Conclusion:** the molecules of carbon-based life are easily produced; they should have been abundant on the early Earth and elsewhere.

**The other very important ingredient is Time**



Recent News

# Searching for Life in the Solar System & Other Systems

Within the Solar System, searches for life will concentrate on where there may be liquid water. The major efforts will be Mars and Europa, although Ganymede, Callisto, Enceladus, and Titan can't be ruled out.

One idea to keep in mind: what if life (present or past) is found on Mars that has a similar chemistry to Earth life?

*Could life have originated on Mars and been transplanted to the Earth, or vice versa?*

*The answer is yes, we may be Martians or Martians may be us.*

*What might we learn from the Perseverance Rover?*

Your author gives a good account of our search for life in the Solar System and a good treatment of how we hope to search for life on other planets. You should have a good idea what the **Habitable Zone** is – it's the region around a star where liquid water may be present on the surface.

(But what possibility does this definition of habitable zone ignore? **LC**)

*It ignores the possibility of tidal heating (e.g. Europa), "geological heating" (Mars?), and other chemicals playing the role of liquid water (e.g. Titan)*

***We'll also have to pay attention to what the JWST finds.***

# Search of Extraterrestrial Intelligence

When we contemplate searching for intelligent life beyond our solar system:

**We have no problem defining what we mean:**

- **A civilization at a sufficient level of technology that it can communicate with us across interstellar distances.**
- **How would we communicate? (LC)**

  The easiest and most economical way is to use radio waves which are easy to produce and receive, and travel great distances at the speed of light (*as fast as anything can go*) without being absorbed.

**How many such civilizations should we expect to exist in the Milky Way Galaxy?**

In the early 1960's, the astronomer Frank Drake (1930-2022) introduced an equation to estimate the number of civilizations in the Milky Way, $N_{civilizations}$

**The Drake Equation:** $N_{civilizations} = N_{HP} \times f_{life} \times f_{civ} \times f_{now}$

$N_{HP}$ = number of **habitable planets** in the MW

$f_{life}$ = fraction of habitable planets that have **life**

$f_{civ}$ = fraction of planets with life where a **technological civilization** arises

$f_{now}$ = fraction of planets with a civilization communicating **now**

# Search of Extraterrestrial Intelligence

**So, what do we get from the Drake Equation?**

- It depends on the numbers that we put in, and we don't really know any of them.
- Based on the Kepler mission, it appears as if most stars have planets, and it is likely that each star would have one in its habitable zone (our solar system has ~two); so maybe $N_{HP} \sim 10^{11}$, i.e. about 100 billion.
- The fraction of habitable planets with life may be high based on things like the Miller-Urey Experiment. If we could find one case of life independently arising elsewhere from Earth, this may be better established.
- We have no idea what fraction of planets that have life will develop into a technological civilization – after all it took 4.5 billion years for Earth to acquire such a civilization (. . *we think*) - *and what would have happened if that asteroid had missed Earth 65 million years ago?*
- How long do technological civilizations last – by our definition, Earth's has only been here for ~60+ years; and if you follow the news, it might not last much longer, so maybe $f_{now}$ is really small.

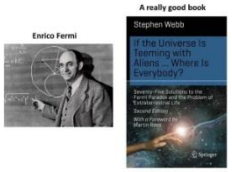
**So estimates using the Drake Equation can range from 0 to billions.**

# Search of Extraterrestrial Intelligence (SETI)

**Has SETI heard anything?**

No, but only a small fraction of the stars in the Milky Way have been examined at a small fraction of the possible frequencies.

**What about Fermi's Paradox?**

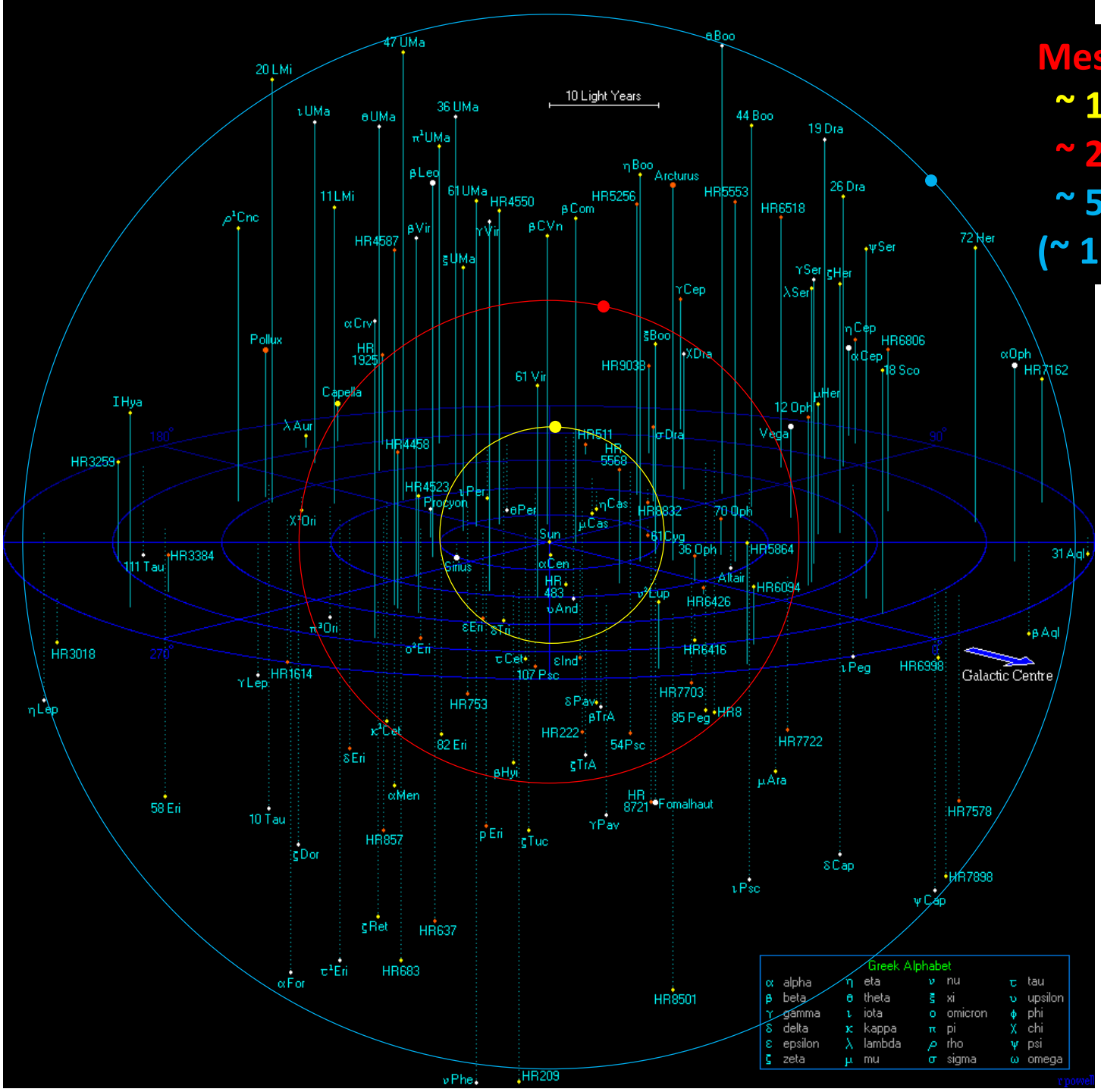



- In the 1950's, the physicist Enrico Fermi posed the question:
  *"Reasonable estimates indicate that galactic civilizations should be numerous and already exist –* ***so where is everyone****?"*
- As Stephen Webb's excellent book indicates, there are many possible explanations for the Fermi Paradox.
- Timothy Ferris demonstrates one in a convincing manner.

**We have also been sending messages – most of them unintended.**

- This is what is beautifully (but not accurately) depicted at the beginning beginning of the movie **Contact (1997)**. **(LC)** **On the next slide is a more realistic depiction.**
- We have also transmitted a deliberate radio message from the Aricebo Telescope in 1974. *(They want to do another one of these, I hear; maybe they should read the The Three-Body Series!)*
- In addition, the Pioneer 10 and 11 spacecraft which are leaving the Solar System each carry a plaque telling about us

Our Messages Passing Nearby Stars out to ~ 50 light years




**Message at**
**~ 15 ly**
**~ 28 ly**
**~ 55 ly**
**(~ 133 stars)**

**Maybe switch this slide to main projector**

**If we all use streaming for our TV, these will stop.**

# A Last Idea for PHY111

**As individuals and as a society, we like to leave monuments behind.**

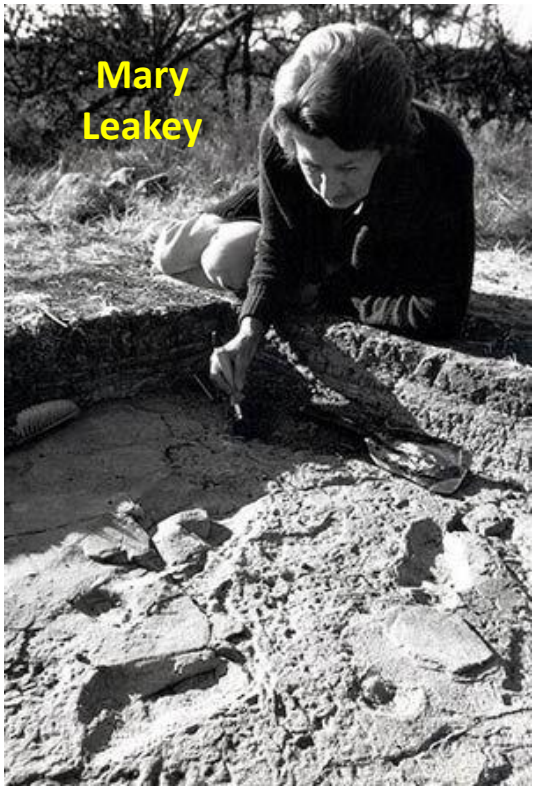
***Why do we do this?***

**Some Famous Monuments**

**The Pyramids**

**Prehistoric Cave Art**

**An Inadvertent Monument, The Laetoli Footprints made ~3.5 My ago by early hominins.**



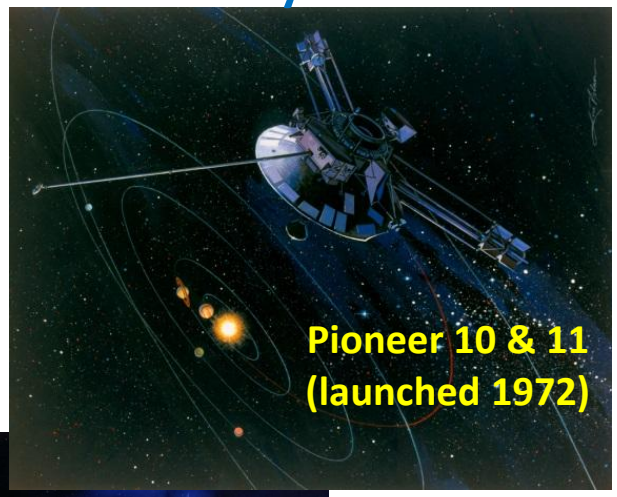

**A Monument to an individual**


***So that when we're gone, it will be remembered that once we were here.***

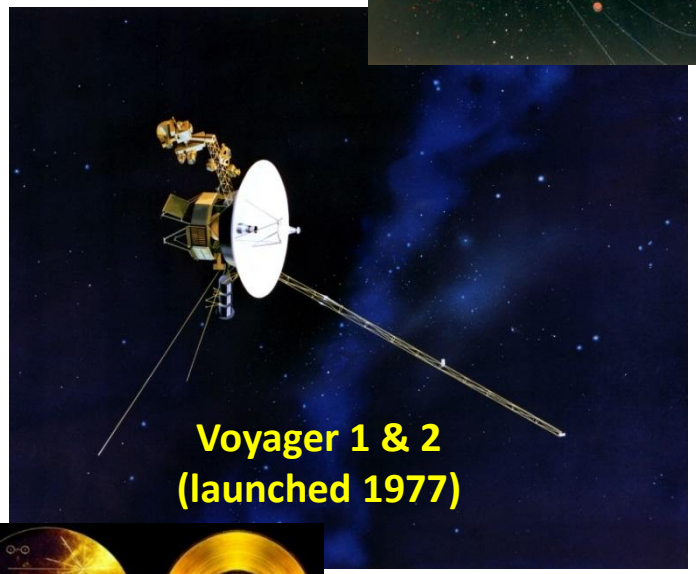
**who was this guy?**

# What are the Most Enduring Monuments of Humanity?

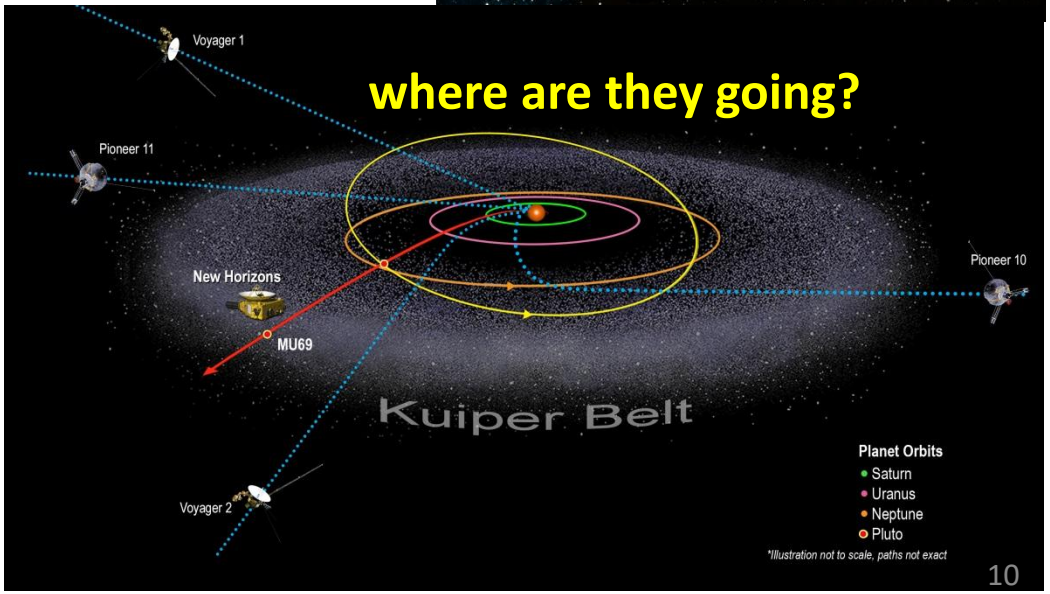
**As of 2025 we have launched 5 spacecraft that have left or will leave the Solar System and never return. They will wander through the Milky Way galaxy for billions of years.**








Records on Voyagers 1 & 2



# What are the Most Enduring Monuments of Humanity?

On each Voyager Spacecraft is a golden record that contains images and sounds of Earth.

*You're seeing and hearing some of those now –* ***what do they say about us?***

***Here's your last assignment for PHY111:*** ***How would you describe US to an intelligent extraterrestrial?***

***Your answer should take ~10 minutes, but you have a lifetime to think about it. Here's what I would say:***

**- We are tremendously curious.**
**- We are great story tellers in our art and literature.**
**- We have a strange love of music.**
**- We take inexplicable joy in something we call humor.**
**- We are incredible engineers.**
**- We are a species of great faith.**

## So What! What's the Big Deal about the Voyager Records?

**If you're an optimist,** then at some time in the future, we will leave the Solar System, and perhaps overtake these spacecraft as we spread out into the Galaxy. **They could then end up as monuments to our time in some galactic museum.**

**If you're a pessimist,** then the Human Species will remain in the Solar System ultimately facing extinction at some point – Shakespeare: ***"Life's but a walking shadow, a poor player, That struts and frets his hour upon the stage, And then is heard no more . . "***

**And when the Sun reaches the end of its life, the Earth and likely every atom ever associated with Humanity will be swept up into the Sun ultimately to be ejected as part of a planetary nebula or to become part of the white dwarf that is the destiny of the Sun.**

***It is a sobering thought, that, if Human Civilization ends, these five spacecraft might be the only Monuments to Humanity that will survive the death of the Sun and the Milky Way's merger with the Andromeda galaxy***

***. . . . to let anyone out there know that once we were here and what we were like.***