ASTR 380: Life in the Universe - Astrobiology
Professor Sylvain Veilleux
Some of Life’s Fundamental Questions

- Are we alone?
- How did life develop on Earth?
- What are the conditions for life?
- Could life happen elsewhere?
- How are we searching for life elsewhere?
Outline

• Overview of the syllabus
• Human perception of the Universe
• What is life?
• Some things that may or may not be necessary to life everywhere
• First look at the Drake equation
Syllabus

• Class webpage:  
  www.astro.umd.edu/~veilleux/ASTR380/fall14


• Class meets TuTh 9:30-10:45 AM, CSS 2400

• My contact information:  
  (301) 405-0282, veilleux @ astro.umd.edu

• TA information: Harry Arnold,  
  (301) 405-1561, harryarnold @ gmail.com
Pre-Requisites

• There are none…
• But this class is designed primarily for non-science majors
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Course Grading

- Homeworks: 25%
  Assigned every ~2 weeks
- Midterm exam: 30%
  Thursday, October 9, 9:30-10:45 AM, in class
- Final exam: 40%
  Tuesday, December 16, 8-10 AM, in class (Cumulative)
- Participation: 5% (simple questions in class)
Letter Grades

Letter grades will be determined from your point total:

97-100  93-97  90-93  87-90  83-87  80-83  75-80  70-75  65-70  60-65  55-60  50-55  <50%
A+     A     A-    B+     B     B-    C+     C     C-    D+    D     D-    F

There will be no extra credit in this class.
Late and Make-Up Policy

• All HWs are due promptly at beginning of class.
• HWs turned in after 9:45 AM will be docked at least 20%.
• No HW accepted after the lecture on the due date.
• All excuses must be valid and documented in writing, in advance if possible.
• If you cannot make a scheduled exam time, tell me in advance and we will arrange an earlier time.
Academic Integrity

• **All work must be in your own words, period!** Copying from our textbook, other books, websites, other students, etc. is an offense.

• If you must quote, put source in quotes and give attribution: *As Carl Sagan said, “billions and billions”* (source: Cosmos)

• Excessive quoting with attribution is not an offense, but it will result in a lower grade; I want your thoughts, not that of a book!

• Best bet: don’t look at sources when writing.
Laptop Policy

• In principle, laptops can allow you to take notes faster and access the class website
• In practice, more likely to be used for non-class purposes :)
• Therefore, if you bring a laptop, you must: Sit in the back rows
  Turn the sound off (no headphones)
• This will reduce distractions…
• I reserve the right to change this policy!
Opinions Encouraged!

• Some aspects of this course are well known
  Basics of astronomy, physics, chem, bio
• But many others are not
  Conditions for life, number of civilizations
• I encourage you to express your own opinions during class!
  Looking for robust discussions
So that you know...

- Biological evolution has been the driver of life on Earth, and it is simple and general enough to do so anywhere. The fact of evolution has been established.
- As a result, we will have several classes on evolution, as well as HWs and exam Qs.
- *If for some reason you are offended by evolution, you should not be in this class.*
Human Perception of the Universe
Simple facts:

The Universe is vast and mostly empty!

The Universe is old.

The elements for life are wide-spread.

Our physical laws appear universal.
Our place in the Universe
Our understanding of the Universe
The Birth of a Star - Part 1

Stellar Nursery

A star begins to form in a nebula, a cloud of interstellar hydrogen gas and dust.

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Globule

The gas and dust compress due to gravitational forces, forming a slowly rotating globule.

Gravity

Gas pressure

The spin, pressure and temperature increase. The globule differentiates into a protoplanetary disk (which may become planets) and a central core (which will become a star).

Globule Collapses

IR and radio waves emitted

Gravitational forces overcome gas pressure; the globule collapses. Cooling occurs and the spin increases.

Protoplanetary Disk and Core
The Birth of a Star – Part 2

Protostar and Protoplanets

An Active, Young Star with Planets

A Young Solar System

The core continues to increase in temperature. When fusion begins, a protostar has formed. The disk coalesces into planets.

The young star emits UV light and other radiation. It can emit focused jets of gas for trillions of miles.

A young solar system has formed. This period of the star’s life is the longest and most stable.

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Our Solar System
Our perception of where life can exist
People have always sought to understand their place in the Universe.

This understanding has always been in the context and the capability of the civilization of the time.
Roots of Modern Science: The ancient Greeks (600-200 B.C.; Thales, Plato, Aristotle, Aristarchus…) developed a tradition of trying to understand the Universe with reason, logic, and mathematics.

- Earth is round
- Size of the Earth
- Size of the Sun
- Size of the Moon
- Distance to the Sun
- Concept of planets
- Earth-centered Universe
- Sun-centered Universe
Modern Science: A way of looking at the Universe

Observations/experimentation is the base – empirical facts

Organize the data around a topic and a question

Devise a hypothesis which is testable – reason and logic

Test the hypothesis against existing data

Make a prediction or devise an experiment – test ideas

Perform experiments/observations to test the hypothesis

Use all information to create a new hypothesis or refine the original hypothesis – build sequentially the body of knowledge
Example: What is Life?

- Which one is alive?
  - A rock
  - A snowflake
  - A virus
  - A bacterium
  - A fly
  - A person
Defining Life

What is life?

Ability to:
create and utilize ordered chemical compounds?
interact with the environment?

The goal of any definition of life is to separate “life” from “not-life” in a sensible way.

a flame moves, contains chemical reactions, can grow – not life.

a human brain cell does not reproduce or move, ceases to function if removed from the brain – life

No definition is perfect!
Key Properties of Biological Life
order
growth and development
energy utilization
response to environment
reproduction
evolutionary adaptation

All life creates chemical order within its boundaries. The organism uses energy to create specific complex molecules – proteins, fats, RNA, DNA – which are central to its existence.

More about this later in the course...
A Fun Exercise: the Drake Equation *(simplified)*

\[ N = N_{HP} \times f_{life} \times f_{civ} \times f_{now} \]

where:

- \( N \) is the number of civilizations in our Galaxy for us to talk to today.
- \( N_{HP} \) is the number of *habitable planets* in our Galaxy
- \( f_{life} \) is the fraction \((\leq 1)\) of habitable planets that actually *have* life
- \( f_{civ} \) is the fraction \((\leq 1)\) of the life-bearing planets on which a civilization capable of interstellar communication has *at some time* arisen
- \( f_{now} \) is the fraction \((\leq 1)\) of the above that have a civilization *now*.

What are your guesses for these factors???
Life can be difficult to define
There are arguments about what is necessary for life
Many stars and galaxies, but not clear what fraction of them host life
Our course will explore many aspects of these questions