Course Description

Astrobiology: The Search for Earth is a small, focused honors course that explores the current efforts to find planets like our own in the galaxy. We will survey the science of astrobiology, examine the techniques being employed to study life in the laboratory and in the environment, and look at the efforts to find other habitable worlds.

General Information

Class Times	LL-225, 12:30-1:30 PM M W F
Required Texts	Online material, supplemental material, and TBD
Instructor	John Armstrong
Office Hours	SL 205, 10:30 AM - 11:30 AM, T/TH, or by appointment
Email	jcarmstrong@weber.edu
Web	http://www.weber.edu/jcarmstrong
Phone	801.626.6215

Course Goals

Life on this planet and the astrophysics of the universe are closely connected. The origin of the universe generated all of the hydrogen and helium that make up the stars, and the events leading up to the catastrophic explosion of a distant supernova created the elements that make up your own body. This course is designed to give you a sense of the scale of the Universe, the events that unfold within it, and how they connect to life on Earth. After this course you should have:

- An understanding of the scale of the solar system, the milky way galaxy, and the universe.
- Knowledge of the science of astrobiology, and how people study life in the universe.
- An ability to examine the universe from a scientific perspective.
- An answer to at least one of the following questions: Where did we come from? Where are we going? Are we alone in the Universe?

Reading and Supplemental Material

Since Astrobiology is a rapidly evolving field, we will be relying on reading assignments from online sources, supplemental material handed out in class, current research papers, and other materials we'll determine together as we go along. Preparing for class by reading the background material is an important component to this course. Rather than covering a "canon" of knowledge during lectures, we will use a lot of our class time for discussion, reflection, and experiment. The reading material will help you form a firm foundation for class.

Assignments

Weekly homework assignments will be assigned on Monday and due every two weeks or so (unless noted) by the end of class on Friday. A complete list of assignment due dates can be found on the schedule. Late assignments are not acceptable unless you make arrangements in advance.

The In-Class Activities

We will be conducting a number of in-class activities throughout the semester. These are designed to give you some hands-on experience with difficult concepts, and, in general, are a lot of fun. Attendance is mandatory for credit. Since many of them require special equipment, you can't make them up after the fact. However, I will be 'dropping' one activity during the course, so if you miss one, don't worry about it.

Projects

Since we are a small group of motivated students, this is our opportunity to delve deeply into the subject through individual and group projects. I plan to have three of these projects throughout the course, and these can take the form of laboratory exercises, position papers, research papers, research projects, and the like. We'll discuss these more as the class progresses, but due dates for these projects are listed in the schedule to help you plan your semester.

Grading Policy

The course grading philosophy assumes that you will learn the most in the class from actually doing stuff, either through homework assignments or in-class assignments. The course grade will be determined as follows:

Assignments	35%
In-Class Activities	20%
Projects (3 at 15% each)	45%

Attendance Policy

I will not be taking attendance in class, but much of your grade relies on regular attendance. I highly recommend you attend class all the time! We plan on having a lot of fun, and using our spiffy new projector, so you really wouldn't want to be anywhere else, would you?

Expectations and Responsibilities

I want to stress upfront that this is a quantitative science course. With that in mind, we will be doing some math. Some of your assignments will require you to employ some mathematical skills, which I will help you refresh/acquire in this course. I expect you to give yourself adequate time to complete the assignments and to put a good faith effort into all of your collaborative work. You should expect me to provide you with as much support as humanly possible, including technical/psychological math support and general sympathy. That said, starting the assignment on the day it is due is an excellent way to dissolve the sympathy part! If you give me enough lead time to help, I will make sure you get it. My office hours are posted, and I can be available at other times if necessary. I am here to make sure you get as much out of this course as you possibly can.

Academic Integrity

Regarding academic integrity, I will enforce policies as laid down in Section IV:D of the Student Responsibilities outlined in the Student Code. Specifically, no cheating or other forms of academic dishonesty will be tolerated. The first instance of cheating will result in a zero on that assignment. The second instance will result in failing the class. You will be working in groups occasionally, however, so you will be required to distinguish the difference between collaboration and cheating. When in doubt, make sure to give credit where credit is due.

Special Accommodations

Any students requiring accommodations or services due to a disability must contact Services for Students with Disabilities (SSD) in room 181 of the Student Service Center. SSD can also arrange to provide course materials (including this syllabus) in alternative formats if necessary.

HNRS1500: Astrobiology: The Search for Earth

Date	Topic	Notes
8/23	Introduction to the Universe	
8/30	Building Blocks of Life	Assignment 1 Due
9/6	Synthesis of Life	Labor Day, Monday September 6
9/13	Limits of Life	Assignment 2 Due
9/20	A Habitable World	
9/27	The Search for Life in the Solar System	First Project Due, Friday, October 1
10/4	Mars	Assignment 3 Due
10/11	Mars	Fall Break, Friday October 15
10/18	Icy Worlds	Assignment 4 Due
10/25	Titan	
11/1	Detecting Extrasolar Planets	Second Project Due, Friday, November 5
11/8	Other Planetary Systems	Assignment 5 Due
11/15	Detecting Life	
11/22	Detecting Life	Thanksgiving Thursday and Friday, November 25 and 26
11/29	Extrasolar Intelligence	Assignment 6 Due
12/6	***FINALS WEEK - FInal Project Due***	

Schedule subject to change

Life on Mars? Name________________________

Goal
Explore the results of the Viking Life Detection experiments.

The Experiments

The Viking 1 & 2 landers (which arrived on Mars in 1976) each carried three experiments designed to detect the presence (or absence!) of life on Mars. These were:

1. **The Pyrolytic Release (PR) Experiment**, which tested for carbon fixation. In this experiment, a soil sample, extracted from the surface by the robotic arm, was exposed to a mixture of CO and CO_2 gas brought from Earth. The gas consisted of a known amount of a radioactive isotope of carbon, ^{14}C. The sample was exposed to this "atmosphere" for five days while a xenon lamp simulated the sun. Afterward, the sample was heated to 625 C to break down and outgas any organic material that might have been manufactured by organisms from the carbon in the atmosphere.

2. **The Gas Exchange (GEX) Experiment**, which tested for metabolic production of gaseous byproducts in the presence of water and nutrients. A soil sample from the surface was partially submerged in water and nutrients and incubated for 12 days in a simulated Martian atmosphere. Gases that might be emitted from organisms could be detected.

3. **The Labeled Release (LR) Experiment**, which tested for metabolic activity. In this experiment, the sample was moistened with a nutrient solution labeled with radioactive ^{14}C. Afterward, it was allowed to incubate for 10 days. Any micro-organisms would consume the nutrient and give off gases enriched in ^{14}C.

Each of these experiments used a **sterile control** consisting of Martian soil taken from the surface and then heat-sterilized to 160 C.

Attached you will find the results from the viking lander experiments. The first experiment shows results in the laboratory for life on Earth. The second experiment shows results from a completely sterilized sample. The third set of results are the actual Viking experiments. Examine the results, discuss possible interpretations of these results with your partners, and answer these questions:

1. What is the purpose of the control?

2. Examine the results of the Viking experiments for the **sample**. What conclusions can you draw from examining the sample alone?

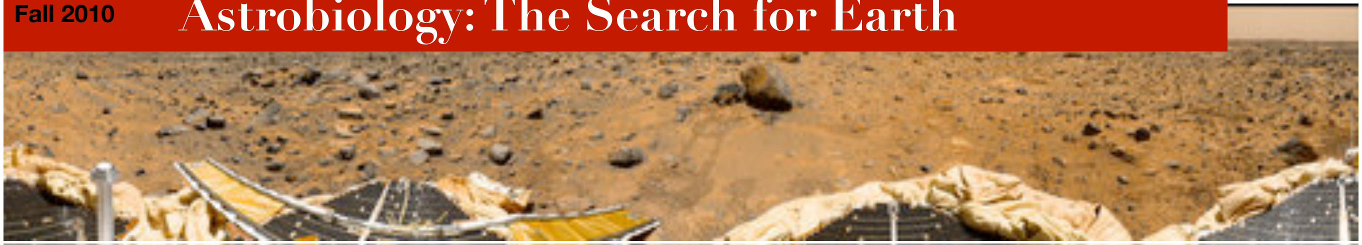
3. Examine the results of the Viking experiments for the **control**. What conclusions can you draw in light of the results from the control?

4. Many scientists think these experiments failed to detect any positive indications of life. What arguments could be used against the notion that these experiments had ruled out all possibilities of life?

5. Can you think of any methods to improve these experiments on future missions? Specifically, what techniques would you suggest?

Viking Life Detection Experiments
Results:

Earth Life (Pre-flight test)	Response of Sample	Response of sterile control
Gas Exchange (GEX)	O_2 or CO_2 emitted	none
Labeled Release (LR)	labeled gas emitted	none
Pyrolytic Release (PR)	carbon detected	none
No Life (Null Result)	**Response of Sample**	**Response of sterile control**
Gas Exchange (GEX)	none	none
Labeled Release (LR)	none	none
Pyrolytic Release (PR)	none	none
Mars - Actual	**Response of Sample**	**Response of sterile control**
Gas Exchange (GEX)	O_2 emitted	O_2 emitted
Labeled Release (LR)	labeled gas emitted	none
Pyrolytic Release (PR)	carbon detected	carbon detected



Assignment 2

1. Given the shear vastness of the Universe, how would you prioritize the search for life? For example, how would you prioritize the search for life in the solar system? How about the search for life outside of our solar system? Clearly describe the strategies and technologies you will need.

2. The following is a list of "biomarkers":

   - Cellular Remains
   - Textual fabrics in sediments
   - Biologically produced organic matter
   - Minerals deposited by biological activity
   - Stable isotopic patterns that reflect biological activity.
   - Atmospheric constituents who relative concentrations require a biological source.

   List these in order of:

   a. The most durable to the most fragile

   b. The most compelling evidence for life to the least compelling evidence for life

   c. Which biomarker are you most likely to find? Which would provide the *best* evidence for life?

3. Amino acids (some of which are found in the proteins used by life on Earth) were synthesized in the Miller-Urey experiment and found in the Murchison meteorite:

   a. Describe the Miller-Urey Experiment. What did the experiment demonstrate? What did the experiment *not* demonstrate?

   b. Examine tables 4.3 and 4.4 in your text, showing the types amino acids generated in the Miller-Urey experiment and found in Murchison. Based on this data, were the amino acids needed for life generated on Earth (through some sort of Miller-Urey-like process) or were they delivered by meteorites?

   c. How confident are you in your answer to b)? Explain your reasoning.

4. Comparative planetology: Using the data from another source (textbook, internet, whatever), complete the table and answer the following questions:

	Venus	Earth	Moon	Mars	Titan
Mass (Earth Masses)					0.02
Gravity (Relative to Earth)	0.91	1.00	0.16	0.38	0.14
Radius (Relative to Earth)	0.95	1.00	0.27	0.53	0.40
Density (Relative to Water) **Water = 1000 kg/m^3**					
Distance to Sun (A.U.)		1.00			
Atmosphere? (Y/N)					
Surface Temperature (K)					80

a. What planet (other than Earth) would you consider most "Earth-like" and what are your reasons?

b. What planet would you target for a "search for life"? Why?

c. What is the general trend in surface temperature as you go from close to the sun to far away from the sun?

d. There are two oddities in the temperature data: Venus and the Moon. Why is Venus so hot if it is only slightly closer to the Sun than the Earth? Why is the Moon colder even though it is at the same distance as the Earth?

e. What general effect does an atmosphere have on the surface temperatures of the planets?

f. Based on your reading, why is Venus too hot, Mars too cold, and Earth "just right". Explain your answer in terms of the role carbon sources and sinks play in the regulating the Earth's climate.

Assignment 03: Mission to Mars! - Due Wednesday, 14 Oct 2010

You are commander of the first human mission to Mars. Your task: explore the planet from orbit, identify key land-forms, select a safe landing site, and assess the surface conditions. To complete this mission, you will require access to the command terminal aboard the *ISS (International Space Ship) Percival Lowell* (or any computer with access to the Internet).

Navigation

Your spacecraft, the *ISS Percival Lowell* (in orbit around Mars), is equipment with a surface analysis platform. Open your web browser and locate this tool at http://mars.google.com.

The surface analysis platform opens with data from the Mars Orbiting Laser Altimeter, which gives information about the elevation of surface features (note the elevation scale bar in the lower left hand corner). From this panel, you can:

- **Pan and scan** - By grabbing in the image and holding down the mouse button, you can move from place to place on the map. You can use the navigation keys at the top left portion of the screen. Double-clicking on a region will transport you there.
- **Zoom in and out** - Using the zoom keys in the top left portion of the screen, you can zoom in and out.
- **Display image data** - You can display visible images (showing the reflected light from the surface) and infrared images (showing images of the infrared radiation) by selecting the image type at the upper right portion of the screen.
- **Search for key land-forms** - Using the "Search" bar at the top of the screen, you can search for key land-forms such as "dunes" or "craters".

The Mission

Using the tools available on the surface analysis platform, select a landing site on Mars for your astrobiology explorations. Select a landing site based on the following criteria:

- **Safety** - Your site should provide a safe landing area for typical spacecraft technology, free of common hazards such as cliffs, crater walls, etc.
- **Scientific Interest** - Your site should be within close proximity (one screen width at highest magnification) of scientifically interesting locations.

What to hand in:

To complete your mission, turn in the following:

- A print-out (or digital image) of your landing site, along with a description (surface properties, elevation, etc).
- A description of the scientific interest of your site. Specifically, what question would you like to answer by going there?

- A posting to the discussion board for this assignment indicating your site for discussion. Determine the region associated with your landing site using the “Regions” button on the analysis platform. Also, comment on someone else’s selection.

Project 1: Presentation on Extremophiles

The goal of the first project is to get you acquainted with the host of extreme organisms that exist on Earth, as well as explore some of the possibilities of environments off the Earth.

Your task:

1. Select a group. Your group should have no more than three people.
2. Choose a microorganism that can be classified as "extreme". To get some ideas, you can start by searching the web for ideas. Wikipedia provides an excellent *starting point* for your research on extremophiles, but should not be your sole source of information.
3. Prepare a 10-15 minute presentation on your organism the addresses the following issues:
    a. What makes this organism extreme?
    b. Describe the environment in which this organism thrives.
    c. Describe the adaptations this organism exploits to live in this environment.
    d. Discuss places elsewhere in the solar system this organism might thrive.

You should prepare your presentation for a general audience who may not be familiar with scientific terms. The challenge here is to present a coherent, complete, and interesting discussion on your organism in the allotted time. With that in mind, *practice your talk* with your partners to make sure that you fit in the presentation time. You should also leave a couple of minutes at the end of your talk for questions from the audience. Your presentation will be evaluated on the following three equally weighted criteria:

- Appropriateness of topic - Did you select an microscopic extremophile from the planet Earth?
- Content of presentation - Did you cover the issues outlined above?
- Presentation quality - Did you prepare a complete and interesting presentation for the target audience? Did you practice the presentation and stay within the time limit?

Project 2: Extrasolar Planets

Now that you have identified candidate planets and their potentially habitable moons, it is time to present!

Your task:

Choose one of the top candidate systems. Using the known properties of the system, you are going to "model" the properties of that system. Some things to consider include (but are not limited to) the following...

i. Where is this star in the night sky?

ii. How far away is this star?

iii. Are there other planets in the system? If so, describe them.

iv. What are the properties of the star?

v. How long is the year?

vi. Assuming the planet is like Jupiter, what is its rotation period?

vii. Assuming the moon is tidally locked, what is its rotation period?

viii. How many "days" in the planet's "year"?

ix. What would the seasons be like?

x. Draw a picture of this system (artistic, schematic, graphical, whatever you are most comfortable with)

xi. Are there any issues associated with giant planets that might be a problem for habitable moons? Things to consider might include magnetic fields from the parent star, frequent eclipses, frequent impact events, etc...

xii. Are there any other special circumstances?

You should prepare your presentation for a general audience not be familiar with scientific terms. The challenge here is to present a coherent, complete, and interesting discussion on your planet in the allotted time. With that in mind, *practice your talk* with your partners to make sure that you fit in the presentation time. You should also leave a couple of minutes at the end of your talk for questions from the audience. Your presentation will be evaluated on the following three equally weighted criteria:

- Content of presentation - Did you cover the issues outlined above?
- Completeness of your "model" - Do you describe the conditions of your world completely and with the appropriate amount of detail?
- Presentation quality - Did you prepare a complete and interesting presentation for the target audience? Did you practice the presentation and stay within the time limit?

Stellar Type	Surface Temperature (K)	Luminosity, Solar Units	Inner Edge, AU	Outer Edge, AU
M5	3170	0.008	0.07	0.18
M4	3290	0.013	0.09	0.24
M3	3400	0.02	0.11	0.29
M2	3520	0.032	0.14	0.37
M1	3660	0.05	0.17	0.46
M0	3840	0.077	0.21	0.56
K7	4150	0.145	0.29	0.75
K5	4410	0.216	0.35	0.9
K4	4540	0.263	0.38	0.99
K3	4690	0.318	0.42	1.08
K1	4990	0.461	0.5	1.27
K0	5150	0.552	0.55	1.37
G8	5310	0.656	0.59	1.48
Sun	5777	1	0.72	1.76
G2	5790	1.07	0.74	1.82
G0	5940	1.25	0.8	1.94
F8	6250	1.1	0.74	1.78
F5	6650	1.2	0.76	1.79
F2	7050	1.3	0.77	1.8
F0	7300	1.4	0.79	1.83

Project 3: SETI

For this final project, you will be preparing a written document on the topic of the Search for Extraterrestrial Intelligence, or on some aspect of the implications, process, likelihood, etc of such an event. I would like to give you the widest range possible of formats for the project, but the work should reflect a thoughtful approach to the topic.

Some formats for the paper can include:

- Research paper on some aspect of SETI
- Popular article on some aspect of SETI, that is, something similar in type, style, and length as a featured article in a popular science magazine
- Creative fiction (or non-fiction) account of some aspect of SETI
- Interview with a scientist or researcher on a SETI topic (other than your professor!)
- Something else? Clear this with me first...

The topic must in some way related to SETI. If you have doubts about the scope of your project, clear it with me first. The length and complexity of your project will be commiserate with the topic and format that you choose. For example, a research paper might run 5-10 pages, including figures and references, depending on the topic. A feature article might be a mere 2000-3000 words, but you will be responsible for layout, images, and voicing the piece for the appropriate audience. Creative works can be of any length, provided they delve deeply into an aspect of SETI not otherwise explored in our reading. In short, the length and breadth of the piece should reflect the topic and the depth of your understanding on the subject. In short, it should be compelling, interesting, and insightful. Simple, right?

To help with this, I'd like to review a first draft of your piece by November 29th. You will receive feedback by the December 1st. Your final draft will be due on Thursday, December 9th, in lieu of a final exam in this course.

Have fun!

Some other upcoming dates:

Here is a quick schedule for the remainder of the term:

Nov 17: The Drake Equation and the Fermi paradox

Nov 19: Continue discussion of Contact, should have read first 1/2 by now

Nov 22: Continue discussion of Contact

Nov 24: Continue discussion of Contact (finish book over Thanksgiving)

Nov 29: Rough draft of Final Project due

Dec 1: Watch Contact in the planetarium (get feedback from rough drafts)

Dec 3: Finish watching Contact in the planetarium

Dec 9: Final Project due.