Fall 2006

Astrobiology: A Special Section of Astronomy

Course Description

Elementary Astronomy is an introductory course in the fundamental workings of the Universe. This course is a special session of elementary astronomy, exploring life in a universal context. Where did we come from? Where are we going? Are we alone? We are going to ask these questions and do our best to answer them!

General Information

Class Times	LL-Planetarium, 8:00 AM M W F
Required Texts	*An Introduction to Astrobiology*, Gilmour and Sephton, ISBN 0-521-54621-4
Instructor	John Armstrong
Office Hours	SL 205, 2:00 - 4:00 PM, M; 9:00 - 10:00 AM, T Th, or by appointment
Email	jcarmstrong@weber.edu
Web	http://physics.weber.edu/armstrong
Phone	801.626.6215

Course Goals

Life on this planet and the astrophysics of the universe are intimately 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?

Assignments

Weekly homework assignments will be assigned on Friday and due in two weeks (unless noted) by the end of class. Late assignments are not acceptable unless you make arrangements in advance.

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. Unless otherwise noted, activities will be held on Wednesdays.

Exams

There will be three equally weighted exams during the course. These serve as a measure of your 're-tained' knowledge and will help you (and me) keep tabs on your progress. If you must miss an exam, please make arrangements in advance. Makeup exams will not be given except under the most ex-treme circumstances.

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. Therefore, the course grade is heavily weighted towards the assignment rather than the exam end of things.

Assignments	50 %
In-Class Activities	20 %
Exams (3 at 10% each)	30 %

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?

Academic Integrity

Regarding academic integrity, I will enforce policies as laid down in Section IV:D of the Student Re-sponsibilities outlined in the Student Code. Specifically, no cheating or other forms of academic dis-honesty 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.

Expectations and Responsibilities

This is a science course that fulfills University requirements for quantitative credit. Some of your assignments will require you to employ some mathematical skills. I expect you to give yourself ade-quate 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. 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 neces-sary. I am here to make sure you get as much out of this course as you possibly can.

Special Accommodations

Any students requiring accommodations or services due to a disability must contact Services for Stu-dents 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.

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Course Schedule

Week Of...	Topic	Reading	Notes
Aug 28	Introduction to the Universe		Assignment 1 Due
Sep 4	Building Blocks of Life	1.1 - 1.5	Labor Day, no class 9/4
Sep 11	Synthesis of Life	1.6 - 1.11	Assignment 2 Due
Sep 18	The Limits of Life	2.5 -2.7	
Sep 25	A Habitable World	2.1 - 2.4	Assignment 3 Due
Oct 2	The Search for Life in the Solar System		Exam 1
Oct 9	Mars	3.1 - 3.4	
Oct 16	Mars	3.4 - 3.8	Fall Break, no class 10/20, Assignment 4 Due
Oct 23	Icy Worlds	4.1 - 4.4	
Oct 30	Titan	5.1 - 5.6	
Nov 6	Detecting Exoplanets	6.1 - 6.8	Assignment 5 Due Exam 2
Nov 13	Other Planetary Systems	7.1 - 7.5	
Nov 20	Detecting Life	8.1 - 8.3	Thanksgiving, no class 11/24
Nov 27	Detecting Life		Assignment 6 Due
Dec 4	Extraterrestrial Intelligence	9.1 - 9.6	
Dec 11	Final Exam Week		

Grading Rubric for Assignments

Points	Requirements
5	Questions are answered thoroughly, thoughtfully, completely, and (when possible) correctly. Assignments are smartly presented (either neatly hand-written or typed). Quantitative problems are worked out completely and correctly, with all work shown.
4	Questions are answered thoroughly and (when possible) correctly. However, arguments are incomplete. Assignments are neatly hand-written or typed. Quantitative problems are complete but with minor errors.
3	Questions are answered thoroughly, but are poorly argued/incorrect. Assignments are neatly hand-written. Quantitative problems are complete with some errors.
2	Questions are answered too briefly or are incomplete with insufficient or incorrect arguments. Assignments are poorly presented or difficult to read. Quantitative problems are complete, but have major errors.
1	Questions have incomplete answers or arguments Assignments are illegible. Quantitative problems are incomplete or incorrect.
0	Question not attempted.

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Sample Question:

Describe a method for detecting life on a planet *outside* of our solar system (that is, orbiting another star). Clearly describe the strategies and technologies you would use.

Sample Answers:

Points	Requirements
5	One possible method is to isolate the light reflected from the planet's surface, and use that light to study the atmospheric constituents. Telescopes being built by NASA use coronagraphs or nulling interferometry to isolate the light, and can examine that light and determine the composition of the planet's atmosphere by analyzing the spectrum in the visible and infrared. The composition of the atmosphere (the existence of water, ozone, or oxygen) could indicate the presence of life.
4	You can use telescopes to examine the light from other planets, and from that tell if there is life. Life affects the atmosphere, and those effects can be seen with the telescopes. The atmospheric conditions (whether or not water, ozone, or oxygen are present) can indicate life.
3	You can use the light from planets and special telescopes to tell if there is life. If the atmosphere has a certain composition, life might be present, and if certain compounds are not present, life is not likely to be there.
2	You can use space probes that go to other planets to explore for other forms of life.
1	You can't tell if there is life on other planets.
0	Question not attempted.

What is life?

	Bacteria	Virus	Tree	Dog	Rock	Earth	Mule	Worker Ant
Needs Water								
Made of Carbon								
Repro-duces								
Evolves								
Converts Matter and En-ergy								
Produces Waste								

What is Life? Name________________________

Goal
Develop a comprehensive definition of life.

Constructing a definition: An analogy...

1. The first step to defining something is to list all of its characteristics. For example, let's say you didn't know a thing about chemistry, and you wanted to answer the question "What is Water?" Write down a comprehensive list of the characteristics of water. Remember, water can be a solid, gas, or a liquid.

2. Based on your characteristics above, write a *comprehensive* definition of water.

3. Are there any problems with your definition? Does it exclude some instances of water? Does it include something that isn't water?

Defining life...
For water we have a comprehensive tool for describing it called *chemistry*. Regardless of all the properties and characteristics you listed, a chemist can say “Water is H_2O.” Any analysis of a material that determines the ratio of 2-to-1 of hydrogen and oxygen has detected water.

We are not so lucky with life, as we have no theoretical framework that describes exactly what life *is*. We are stuck with listing the characteristics of life as we know it, and trying to identify general principles that can be extrapolated to life as we *don’t* know it.

Constructing the definition of life

1. With your partners, brainstorm a list of the characteristics of life. What is it made of? What does it do? Remember to consider *all* forms of life (not just humans).

2. On the following page, you’ll find a table listing some possible characteristics of life, with some space to add some more that you determined in your brainstorming session. Add yours to the list (use an extra page if you have to) and evaluate the forms of “life” listed on the chart (note that planet Earth is listed for fun...somebody should ask me about that). In each box, write a “Yes” or “No” if it exhibits or satisfies your condition for “life”.

3. Are there any examples of “life” that meet all of your conditions? None of them?

4. Write down your *comprehensive* definition for life. Are there any forms of life excluded? Can you list anything you know is non-living that might meet your definition for life?

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 xeon 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 by-products 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 rules 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 03 - Due Friday, 29 Sep 2006

1. Comparative planetology: Using the data from your textbook (Appendix A), 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.

g. Also, please visit the assignment 3 discussion (on vista4.weber.edu) and post at least one comment and respond to at least one comment.

Assignment 03: Mission to Mars! - Due Wednesday, 18 Oct 2006

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 some else's selection.

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Assignment 06: SETI - Due Friday, 08 Dec 2006

The purpose of this assignment is to determine the number of alien civilizations in our galaxy, compose a message, and discuss some of the implications for humanity if we do (or do not!) find life in the galaxy.

Finding and communicating

1. Using the Drake Equation, estimate the number of civilizations in our galaxy. In addition to reporting the total number of civilizations, make sure you specifically indicate all of your values, and briefly discuss why you made these estimates.

2. Using what you have learned in class and resources from your book, compose an image to send to a communicating civilization. Since you are on a tight budget, you can only send 143 bits of information, corresponding to an 11x13 image. Hand in your completed image and a description of what governed your decision to choose this particular image?

3. Assuming you sent your image 100 times over the span of 10 hours, compare the duration of your transmission to the distance between us and the nearest star (α Centauri, about 4 light years away). Discuss the likelihood of any α Centaurians detecting your message.

Where are they?

4. What is the Fermi Paradox? That is, what are its main assumptions and what is the "paradox"?

5. One solution to the Fermi Paradox suggests that we are the most advanced civilization in the galaxy. How does that conflict with the Copernican Principle?

6. What are some other possible solutions to the Fermi Paradox?

Who speaks for Earth?

7. Imagine a signal from a communicating civilization is received on Earth, detected simultaneously by many astronomers in many nations. Describe the effect this would have world events, both globally, regionally, and in your personal life.

8. Imagine this signal is directed specifically at Earth. Should we respond? If so, how should we respond?

9. Discussion Question: Go online (http://vista4.weber.edu) and respond to the graded discussion question for this assignment: If you could ask only one question of an extraterrestrial civilization, what would it be? What are the implications of the "yes" answer and what are the implications of the "no" answer?

Exam I
PHYS 1040: Astrobiology
Dr. John Armstrong
Due Oct. 7th, 2005 **By Close of Testing Center**

NAME:

Instructions

This exam is closed book, closed notes. You may have a calculator, **NO OTHER RESOURCES ARE ALLOWED!** For full credit, please make sure to explain your answer. Please place all answers on the exam sheets provided. Good luck, and have fun!

Questions

1. (5 pts) Ranking task: list in order of the oldest event to the most recent event:
   (a) Rise of macroscopic life
   (b) Formation of hydrogen and helium in the big bang
   (c) Synthesis of RNA/DNA
   (d) Synthesis of molecules in the interstellar medium
   (e) Synthesis of heavier elements in stars and stellar explosions
   (f) Rise of oxygen
   (g) Synthesis of amino acids and other complex organic molecules
   (h) Single-celled organisms

2. (5 pts) Ranking Task: List in order of most abundant to least abundant element in the Universe:
   (a) Helium
   (b) Oxygen
   (c) Hydrogen
   (d) Carbon
   (e) Nitrogen
   (f) Iron

3. (5 pts) Which of the following lists the important macromolecules necessary for life?
   (a) Lipids, Buckey balls, proteins, and nucleic acids
   (b) Hydrogen, carbon, nitrogen, and oxygen
   (c) Lipids, water, proteins, and nucleic acids
   (d) Lipids, carbohydrates, proteins, and nucleic acids
   (e) Lipids, carbohydrates, proteins, and carbon
4. (5 pts) Of the list of biomarkers, which is the least durable?
   (a) Cellular remains
   (b) Textural fabrics in sediments
   (c) Biologically produced organic matter
   (d) Biologically affected mineral deposits
   (e) Isotopic patterns
   (f) Biologically produced atmospheric gases
5. (10 pts) What are two possible sources for complex molecules (like amino acids) available to life on earth?
6. (10 pts) Describe the Miller-Urey experiment. What did it demonstrate? What did it **not** demonstrate?

7. (5 pts) What is the single largest energy source for the Earth?

   (a) The Sun
   (b) Volcanism
   (c) Electrical discharge
   (d) Impact heating
   (e) UV radiation

8. (5 pts) What two mechanisms play the most important role in determining the surface temperature of a planet?

   (a) Absorbed solar radiation and internal heat
   (b) Absorbed solar radiation and the greenhouse effect of the atmosphere
   (c) Absorbed solar radiation and the distribution of clouds
   (d) Absorbed solar radiation and the number of impact events
   (e) None of these

9. (5 pts) Define the Habitable Zone.

10. (5 pts) What physical process determines its inner edge? Be specific.

11. (5 pts) What physical process determines its outer edge? Be specific.

12. (5 pts) What effect will a slowly increasing luminosity have of a star's circumstellar habitable zone?

13. (10 pts) Name at least two places in the solar system that are outside the continuous habitable zone and yet may have an environment suitable for life.

14. (10 pts) The goldilocks story says that Venus is too hot, Mars is too cold, and the Earth is just right. What happened on Venus to make it so hot? What happened on Mars to make it so cold?

15. (10 pts) I am sure there is something that you know that hasn't been asked on this exam. Write down a question related to astronomy and answer it. Your question can be related to any topic in the class, covered in this exam or otherwise. You will be evaluated for posing a concise question and providing the correct answer.

Exam II
PHYS 1040: Astrobiology
Dr. John Armstrong
Due Nov. 11, 2006 **By Close of Testing Center**
NAME:

Instructions

This exam is closed book, closed notes. You may have a calculator, **NO OTHER RESOURCES ARE ALLOWED!** For full credit, please make sure to explain your answer. Please place all answers on the exam sheets provided. Good luck, and have fun!

Questions

1. (5 pts) Which of the following planets is most likely to hold onto an atmosphere?
   (a) A planet with low temperature and volcanism.
   (b) A planet with low mass and low rotation rate.
   (c) A planet with high mass and fast rotation rate.
   (d) A planet with high mass and low temperature.
   (e) A planet with low mass and high temperature.

2. (5 pts) Which of the following features of the solar system are best explained by the nebular theory of planet formation
   (a) Most of the planets orbit in the same direction around the Sun, rotate in the same direction, and have roughly circular orbits.
   (b) The inner planets rotate quickly while the outer planets have very slow rotation.
   (c) Most of the asteroids in the asteroid belt orbit in the same direction with circular orbits.
   (d) The masses of the planets are precisely determined by the nebular hypothesis.

3. (5 pts) What are the two strongest pieces of evidence we currently have for a liquid water ocean under the icy crust of Europa?
   (a) Spectra indicate a water ice surface and measurement of the tidal flexing of the surface, consistent with a 100 km liquid water ocean under 10 km of ice.
   (b) Spectra indicate a water ice surface and magnetic induction from Jupiter, measured by the Galileo, is consistent with a 100 km liquid water ocean under 10 km of ice.
   (c) Magnetic induction from Jupiter, measured by the Galileo, is consistent with a 100 km liquid water ocean under 10 km of ice and tidal flexing of the surface.
   (d) Spectra indicate a water ice surface and deep surface drilling has detected liquid water under 10 km of ice.

4. (15 pts) Each of the items below describe a potential future discovery about Mars. In light of our current understanding, label each as “likely”, “possible”, or “total baloney”. In one sentence, why?

   (a) We discover a string of very active volcanoes in the old, heavily cratered southern highlands.

   (b) We find subterranean pools of liquid water on the slope of Olympus Mons.

   (c) A sample-return mission brings back evidence of microbes as well as martian plants, trees, and animals

   (d) A re-analysis of the Viking Life experiments leads us to the convincing conclusion that life actually exists on Mars today.

5. (15 pts) Each of the items below describe a potential future discovery about the outer solar system icy moons. In light of our current understanding, label each as“likel”, “possible”, or “total baloney”. In one sentence, why?

   (a) We find a crater on Io that formed as a result of an impact during formation of the solar system, 4.4 billion years ago.

   (b) The surface of Titan turns out to have very few impact craters.

   (c) In another solar system, we find a Jupiter-like planet with four moons that experience significant tidal heating.

   (d) We discover that Europa, Ganymede, and Callisto all have life, but by far the most abundant and most diverse is Callisto.

6. (15 pts) Tidal Heating:

   (a) Show, with a picture and a brief description, how tidal heating arises as the result of gravity and can persist as a result of orbital resonances.

   (b) Describe the affect this has on the Io and Europa.

   (c) Based on your understanding of tidal heating, what is the likelihood that Ganymede and Callisto have subsurface oceans? Why or why not?

7. (10 pts) Explain why icy moons and gas rich planets tend to form far from our Sun, and rocky worlds (like the Earth) tend to form close to our Sun?

8. (10 pts) In view of what we know about the present day conditions on Mars, where are the most probable environments for the survival of present-day life on Mars? Be sure to justify your answer.

9. (10 pts) Why isn't liquid water stable on the surface of Mars? In other words, describe what would happen to an water ice cube if left on the surface of Mars near the equator?

10. (10 pts) I am sure there is something that you know that hasn't been asked on this exam. Write down a question related to astrobiology and answer it. Your question can be related to any topic in the class, covered in this exam or otherwise. You will be evaluated for posing a concise question and providing the correct answer.

Final Exam
PHYS 1040: Astrobiology
Dr. John Armstrong
Due Dec 14, 2006 **By Close of Testing Center**
NAME:

Instructions

This exam is closed book, closed notes. You may have a calculator, **NO OTHER RESOURCES ARE ALLOWED!** For full credit, please make sure to explain your answer. Please place all answers on the exam sheets provided. Good luck, and have fun!

Questions

1. (10 pts) **Science or non-science?** The following describe hypothetical scientific discoveries in the near future. Label each as "possible" or "total baloney", including a one sentence description describing your answer.

   (a) A brilliant teenager working in her garage discovers a way to build a rocket that burns coal as its fuel and can travel at half the speed of light.

   (b) Members of the first crew of interstellar travelers, who left the Earth in 2165, return to earth in 2450 looking only a few years older than when they left.

   (c) Aliens from a distant star system invade the Earth with the intent to destroy us, but we successfully fight them off when their technology proves no match for our own.

   (d) SETI Astronomers find a signal from an alien intelligence living on one of the earth mass planets orbiting a pulsar.

2. (10 pts) **Would you believe it?** The following headlines represent *possible* future scientific results. Explain whether or not your would believe this headline if you read it on the date published, and explain why.

   (a) February 16, 2009: Astronomers conclude Earth-sized planets don't exist

   (b) January 9, 2008: Spectrum reveals unmistakable evidence of life on a "Hot Jupiter'

   (c) November 10, 2010: New images show oceans on an extrasolar planet

   (d) November 7, 2050: New images show oceans on an extrasolar planet

   (e) October 1, 2009: Astronomers announce first detection of an Earth-sized extrasolar planet

   (f) March 30, 2027: More than one-third of stars have habitable planets

   (g) September 15, 2007: Giant planet found in our solar system beyond Pluto

3. (10 pts) Use the Drake Equation to estimate the number of stars in our galaxy that are home to an intelligent species. List the estimates for all of your parameters:

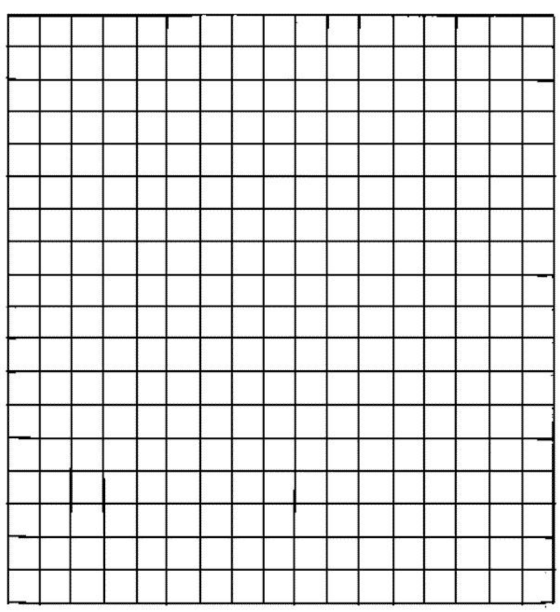
Parameter	*Estimate*
R = star formation rate	10 stars per year
f_s = Fraction of suitable stars	0.5
f_p = Fraction of stars with planets	0.1
n_e = Number of Earth-like planets per star	
f_l = Fraction of planets Earth-like planets with primitive life	
f_i = Fraction of planets with intelligent life	
f_c = Fraction of intelligent life able (and willing!) to communicate	
L = Lifetime of communicating civilization	
$N = R f_s f_p n_e f_l f_i f_c L$	

Will we make contact with another extraterrestrial species in your lifetime? Explain.

4. (10 pts) We receive the following 15 digit message from an alien transmission:

101011110110101

Using the grid below, decipher the message. Are we likely to received a message with this content from outer space?



5. (10 pts) Consider the following methods for detecting extrasolar planets:

   (a) Direct detection
   (b) Transits (or occultation)
   (c) Astrometry
   (d) Doppler spectroscopy (or the radial velocity method)

   Which method is the most successful to date?

   Which method is most sensitive to large planets close to the central star?

   Which method is most sensitive to large planets far from the central star?

   Which method is likely to discover the first earth sized planet outside our own solar system?

6. (10 pts) Choose one of the methods above and describe how it works. Be specific.

7. (10 pts) Suppose that an exoplanet has an extensive biosphere very different from the Earth's that is not based on water and where photosynthetic processes do not release oxygen into the atmosphere.

   (a) List the clues that could have otherwise been used to establish that an Earth-like biosphere existed, but that are no longer relevant in this case.

   (b) What methods could you use to establish that a biosphere different from Earth's did exist on this planet?

8. (10 pts) Describe one *detectable* way life can altar a planet?

9. (10 pts) What are the two postulates of Einstein's theory of Special Relativity? What is 'Special' about this theory – that is, what does General Relativity take into account?

10. (10 pts) I am sure there is something that you know that hasn't been asked on this exam. Write down a question related to astrobiology and answer it. Your question can be related to any topic in the class, covered in this exam or otherwise. You will be evaluated for posing a concise question and providing the correct answer.