ASTROBIOLOGY: LIFE BEYOND EARTH, GEO 331, (3 CREDITS), FALL 2019

Course Catalog Description: Astrobiology: Life Beyond Earth evaluates the potential distribution of life in the Universe, presents the science and technology used to search for life, and explores the societal impacts of its discovery.
Attributes: CSST**:** Successful completion of this course fulfills OSU's Baccalaureate Core requirements in the core synthesis category under Science, Technology, and Society.
Recommended: Before taking this course, students should have completed their Baccalaureate Core Perspectives science course requirements (12 credits of biological and physical science lab courses).

Course Rationale and Topics:

The search for life beyond Earth has been contemplated for centuries and its discovery will be one of humankind's most transformative achievements. The advances in science and technology needed to search for extraterrestrial life lead us to believe that, if it exists, it will be discovered during the lifetimes of today's students, who could be involved in this discovery. This field of inquiry and exploration, often referred to as astrobiology, investigates the possibility of life's existence beyond Earth. Astrobiologists seek to answer our most profound questions: "Is there life and are there intelligent beings elsewhere in the universe?" The field is deeply interdisciplinary; it relies on physics and astrophysics, chemistry and biochemistry, biology and microbiology, geology and planetary science, philosophy, sociology, and evolution of the universe from the Big Bang to the present to address these fundamental questions. Imbedded in our curriculum are important questions for society such as, "Should we reveal our presence to extraterrestrial civilizations? What are the potential societal impacts of the discovery of life elsewhere? Will Earth leave a legacy for other civilizations to ponder? Are there limits to the survival of intelligent life?"

The course starts with the size and age of the Universe and ancient and modern thinking on the possibility or other intelligent life. We explore how, when, and where chemical elements are created in the Big Bang and in stars and consider when first life could have appeared in the Universe. This is followed by a philosophical and scientific exploration of the questions, "What is life?", "Where and how do basic organic compounds form in the absence of life?, "What are the ideas about simple chemical compounds self-assembling into living matter?", and "Can non-organic life forms exist?" We explore the "tree of life" and life at extremes of heat, radiation, pressure, pH, dryness, starvation, and toxins. We then investigate galactic and stellar zones of habitability and recent discoveries of planets that may have water on their surfaces. We follow the 4.5 billion years from Earth's formation to the appearance of intelligent life and the six barriers that life overcame that allowed it to become intelligent. Next, we discuss the significance of these barriers for the rise of intelligent life around other stars. The course draws on results from the Mars landers and rovers and their search for life and habitable environments. We explore other potentially habitable bodies in our solar system such as the icy moons, Europa and Enceladus. The course concludes with a consideration of the Fermi Paradox, panspermia, our attempts to message extraterrestrial life, how many civilizations may learn of our existence, and philosophical and sociological questions associated with our search for life, and the potential future barriers that may limit our ability to search for life. Technologies and techniques used to explore the cosmos for habitable planets and to search for life are incorporated throughout course.

GEO 331, *Astrobiology: Life Beyond Earth*, provides students with the basics of the field of astrobiology. The course augments students' backgrounds that are acquired by completing Baccalaureate Core science perspective courses. Fundamental concepts of the basic sciences of

chemistry, biology, physics, and geology that are relevant to the course are incorporated in the instruction.

Course Structure

To cover these topics we provide background in relevant elemental synthesis in the Big Bang and in stars, stellar evolution, age and evolution of the Universe and Earth, and physics, mathematics, chemistry, biochemistry, biology, geology, and planetary science relevant to astrobiology. This background precedes discussion of the origin of life, galactic and planetary habitability, life in extreme chemical and physical environments, history of life on Earth, the tree of life, the probability of extraterrestrial life, methods of searching for life, and if we are not the only intelligent life in the Universe why have we not found it. The material is presented in short lectures on the basic concepts of the topic of the week and in-class, team activities or discussions that reinforce the concepts. Out-of-class reading assignments are background for the lectures and out-of-class activities expand on the in-class activities. We take students on a field trip to gaze at planets, the Moon, stars, and the Andromeda galaxy and a field trip to collect methane made by microorganisms and then use it to perform work.

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Notes about emails:
(1) To contact us, please use your ONID email account so messages do not go to junk mail.
(2) Include GEO 331 and a topic in the subject line. (Example: GEO 331 assignment question).
(3) If we feel other students in the course will benefit from our response to your email, we will send our response to all students in GEO 331.

Class Meetings: Three 50-minute lectures/class meetings per week on Mon, Wed, and Fri.
Start Time: 10:00 Building and Room: WILK (Wilkinson) 235.

Course Website: Canvas will be used to distribute materials. Access Canvas by typing https://oregonstate.instructure.com into your browser search window and then log in with your ONID username, password, and 6-digit number from your DUO two-factor authentication token. DUO authentication will be mandatory in 2019. Here is the link, https://is.oregonstate.edu/duo/students.

Recommended Textbook: Catling, D.C. 2013. *Astrobiology*. Oxford University Press (about $10.) One copy will be on reserve in the Valley Library.
Other Recommended Materials: (1) Domagal-Goldman SD, et al. 2016. The Astrobiology Primer v2.0. Astrobiology 16:561-653. Available free, on-line. (2) Open-source material will be provided as pdfs posted in Canvas. (3) Web sites for additional resources will also be posted in Canvas.

Learning Outcomes: Students taking GEO 331 will be expected to:
1. Use new vocabulary and concepts from the textbook and other assigned materials in classroom discussions, writing assignments, field trips, and quizzes.
2. Use these new concepts and terrestrial analogs to devise strategies and think critically to plan observations that could identify evidence of present and/or past extraterrestrial life.

3. Discuss the connection between astrobiology and societal and ethical issues.
4. Demonstrate knowledge of technology and the basic physical, chemical, biological, mathematical, and geological principles that are relevant to astrobiology.

Students in the baccalaureate core course in science, technology, and society will be expected to:
1. Analyze relationships among science, technology, and society using critical perspectives or examples from historical, political, or economic disciplines. In-class, out-of-class exercises, weekly assignments, and exam questions will test understanding of the size and age of the Universe and Milky Way galaxy, a method of estimating the number of planets in our galaxy that harbor life, the technology needed to find and observe planets around other stars, life forms in extreme environments, and understanding of the NASA life detection experiments on Mars. Discoveries made with new technologies in the past four decades have shifted our thinking from Earth- and human-centric views of the Universe to the recognition that Earth is one of billions of planets in one galaxy amongst billions, and that it is the only planet that we know of on which we can currently survive. Understanding of political and economic background of these discoveries and of our changing view of our place in the Universe will be evaluated in students' responses to reading assignments and in classroom discussions.

2. Analyze the role of science and technology in shaping diverse fields of study over time. Technology and the four basic fields of science advanced together to bring us to this exciting time in the search for life in the Universe. Physics describes the origin and evolution of the Universe. Chemistry tells us when, where, and how the ingredients for life arose. Biology explains the molecular processes that govern life on Earth and life's rise from single cells to intelligence. Geology provides the background for understanding how our planet has remained habitable for more than three billion years and the geology of other planets constrains our search for life, as we know it. The course draws on these fields of science and technology and helps us understand when and where life could have first appeared or may now exist. Students will be evaluated on their understanding of the aspects of the four basic sciences that are relevant to astrobiology. Students will be assessed on their understanding of the physics, chemistry, biology, and geological covered in lectures, readings, exercises, and field trips. Exams, weekly assignments, in-class activities, participation in classroom discussions and the writing assignment will be assessed.

3. Articulate in writing a critical perspective on issues involving science, technology, and society using evidence as support. Students taking this course will use knowledge gained in lectures, readings, discussions, and out-of-class assignments to articulate and demonstrate in writing an understanding of current efforts to identify where life might occur and how we might find it. In one writing assignment of at least 1250 words and using at least two outside sources students will identify a target to investigate for life or an approach for finding life, an hypothesis, a means of testing the hypothesis, and issues and challenges such as planetary protection, cost, societal relevance, and conflicting ethical values.

Critical thinking:
Development of the ability to think critically is one goal of this course. The coursework, including outside readings and in-class lectures, will build a framework of knowledge in astrobiology subject matter. This knowledge, along with what the teachers and the students bring to the class as a foundation in their respective subject areas, will be used during in-class group activities, debates, discussion, and the writing assignment to practice skills consistent with critical or scientific thinking. Critical thinking will be assessed during in-class discussions (based on the nature of the student contributions), through selected questions in the quizzes, and as a graded component in the writing assignments.

As we define it, critical thinking is the ability to think for yourself and to be creative in your thoughts. It involves a few steps:
1. Observe or read to gather information.
2. Question, evaluate, doubt, verify the information that you have gathered.
3. Accept ideas that are consistent with reading or observation or create verifiable alternate explanations.

Example of critical thinking (from the first class assignment):
The readings for this assignment are Catling *Astrobiology, A Very Short Introduction* p. 120 to 124 on the Drake Equation and the Fermi Paradox and the website: http://frombob.to/drake.html
By reading the material you are gathering information – the first step in critical thinking. There could be many statements in the readings you wish to evaluate, question, doubt, or verify. You might question the value of 2/3 used for the fraction of stars that have planets. You could question if the Drake Equation is the best way to estimate N. For this assignment write a question about something in the readings that you want to evaluate, or that you doubt (with good reason) and want to verify.

What we provide:
During each class session we will present and discuss with you facts, ideas, strategies, and philosophical questions broadly related to the question, "Is there life or even intelligent life anywhere else in the Universe?" Reading assignments and worksheets will be available on Canvas in a timely manner. Lectures will be interspersed with in-class discussions and projects. Grades for assignments and exams will be posted within a week of the assignment's due date or exam date. We will start and end each class on time. We will have regular office hours so that students can visit to discuss interesting or challenging concepts.

Our expectations of you:
1) Prepare and submit each assignment in class by the due date and time, 2) attend class, arrive on time and stay until the end, respect your fellow students, and abide by the university's rules of conduct, and 3) participate in classroom discussions and encourage others to participate. For more details, see the Classroom Principles posting in Canvas, Week 0.

How to do well in this course:
(1) OSU's rationale for Baccalaureate Core courses states, "*Students are encouraged to complete their baccalaureate core perspective requirements before taking the Science, Technology, and Society course.*" Your instructors for *Astrobiology: Life Beyond Earth* highly recommend that you complete your *baccalaureate core perspective requirements in physical and biological sciences before enrolling in this course.*
(2) Be sure your expectation of the amount of work required for the course matches our expectation for the amount of work needed to do well in the course. We expect you to come to class having done the assignment. Out of class assignments are designed to require up to two hours each so this means up to two hours of out of class work per class.
(3) For out of class assignments follow all instructions and complete all sections.
(4) Attend every class, but we recognize that absences may be unavoidable. We provide a form in Week 0 for you to tell us about planned absences. We ask that you sign into each class on the sheet provided as you enter.
(5) We recommend that you view lecture powerpoints before class and take notes during lecture.

(6) Exam questions come from assigned readings, powerpoint presentations, out-of-class assignments, in-class activities, and field trips. Be sure you understand material that is covered more than once in the lectures, readings, and exercises. Be able to draw and label diagrams that are discussed in detail in lectures. (For example, the Hertzsprung-Russell diagram.)

Weekly Plan

Classes on Monday, Wednesday, Friday, except for holidays and Monday of Week 0.
Each class will consist of one or more of the following activities: short lecture, discussion, in-class exercise or activity, or a quiz. A reading and writing assignment or out of class exercise will be assigned to prepare you for most classes. The class preparation assignments are designed to take two hours or less. In Week 0 on Wednesday we will review the syllabus, solicit your opinions about extraterrestrial life, ask you to tell us about your education background, major, and interests and give an assignment that will be due and discussed on Friday. For the rest of the term we will assign reading and writing exercises or out-of-class exercises that are the background for the upcoming class. **Each assignment must be turned on the day that it is due at the end of the class meeting time.**
Assignments submitted after class *and before one week after the due date* will have a maximum point value of ½ the original value. Assignments submitted more than one week late will be read, annotated, and returned but will have no point value.

Descriptions of Graded Items

Office Visit: During the first two weeks of class sign up for a 15-minute appointment with either Dr. Colwell or Dr. Fisk. We can talk about your preparation for the class, your interests, the assigned paper, and your expectations for the course.
Paper: The paper, writing guidance, and our expectations for completing it will be posted in Canvas and described in the first week of class.
Twenty Assignments: The 20 assignments will be either an out-of-class exercise or a reading. These are designed to help you prepare for class. For each reading assignment we ask you to include (1) your name at the top, (2) the main points of the reading, (3) a list of vocabulary that is new to you and the definitions, (4) a list of fuzzy concepts, for which you would like clarification, (5) at least one Aha! concept (see box), and (6) a question that you state that frames an aspect of critical thinking. (Example question: "What factors would make planets around distant stars presently invisible to our detection and why?") Out of class exercises will be posted in Canvas or handed out in class.
Three Quizzes: We will have three 20-minute in-class quizzes. Their dates are given in the Lecture Schedule at the end of the syllabus.
Final exam: This will be held during final exam week.

*__Aha! concepts__ are flashes of insight, possibly newly recognized facts or principles, upon which new ideas can develop. Here are some examples:
1. Answer the question: "What is new and how does it connect with what I already know?" Example: "I knew about the periodic table of the elements, but now I have some idea of how and when the elements were created."
2. Answer the question: "What new concept is presented and what do I think about it?" Example: "The Fermi Paradox asks why have we not been contacted by aliens and offers several possible answers."
3. Answer the question: "How do we know a specific fact?" Example: "The Universe is 13.8 billion years old. The Hubble constant, which is measured by observing distant galaxies, gives a rough estimate of the age of the Universe."

Attendance: A sign-in sheet will be available during class.

Discussion: We expect everyone to participate in at least three classroom discussions. We will learn your names as quickly as possible to be able to credit you with participation. Until that time we ask that you state your name at the beginning of your comment or question. We will count participation as (1) the initiation of a discussion by offering a comment or asking a question AND an additional contribution to the topic, (2) more than one contribution to an ongoing discussion, or (3) presenting a summary of a small group discussion to the class. Through the quarter please **be concise** in your discussions.

Graded Items	**Points**	**Percent**
Office Visit (by October 9)	15	4
Outline of paper (by October 11)	15	4
First draft of paper (by November 1)	30	7
Final paper (November 22)	60	14
20 Assignments, 4 points each	80	19
3 Quizzes, 30 points each	90	21
Cumulative Final Exam	80	19
Attendance (1 point per class meeting)	30	7
Classroom discussion participation	20	5
TOTAL	420	

Field Trips

We will hold two required field trips. One field trip will be to a local pond to demonstrate a signature of life and power of swamp gas and to discuss its importance with respect to astrobiology. The other field trip will be on campus in the evening to observe stars, planets, maybe a meteor or two, and a galaxy or two. This field trip will be scheduled according to the weather and the phase of the moon. Flexibility of field trip dates will accommodate all student schedules. Topics discussed on the field trips can be included on the quizzes.

Grades:

We will use A through F grading. We will grade writing and other out of class assignments, quizzes, and a final exam, and participation, which includes an office visit, attendance, and classroom discussion. The maximum points available for each graded item is given in the table above. The total available points for the term is 420. Your percent score will be your total points from all graded activities divided by 4. (That is, if you get 400 of the total 420 points your percent is 100%).

Letter grades will be assigned as follows:

Letter grade	Minimum %	Maximum %	Minimum points	Maximum points
A	≥ 93		≥ 372	
A-	≥ 90	< 93	≥ 360	< 372
B+	≥ 87	<90	≥ 348	< 360
B	≥ 83	<87	≥ 332	< 348
B-	≥ 80	<83	≥ 320	< 332
C+	≥ 77	<80	≥ 308	< 320
C	≥ 73	<77	≥ 292	< 308
C-	≥ 70	<73	≥ 280	< 292
D+	≥ 67	<70	≥ 268	< 280
D	≥ 63	<67	≥ 252	< 268
D-	≥ 60	<63	≥ 240	< 252

F		<60		< 240

Statement regarding students with disabilities

"Accommodations for students with disabilities are determined and approved by Disability Access Services (DAS). If you, as a student, believe you are eligible for accommodations but have not obtained approval please contact DAS immediately at 541-737-4098 or at http://ds.oregonstate.edu. DAS notifies students and faculty members of approved academic accommodations and coordinates implementation of those accommodations. While not required, students and faculty members are encouraged to discuss details of the implementation of individual accommodations." Types of accommodations are described at https://ds.oregonstate.edu/gettingstarted. The disability access services email is disability.services@oregonstate.edu.

Link to OSU Statement of Expectations for Student Conduct

Please read the information presented by the Office of Student Life on Student Conduct & Community standards: http://studentlife.oregonstate.edu/code. We strongly suggest you read the material on this site at the "Academic Conduct", the "Code of Student Conduct", and the "Reporting Incidents" links. These links have important information on academic dishonesty (cheating, plagiarism, etc.). Read this material; we take cheating and plagiarism very seriously as does OSU. Also extremely useful is the Harvard Guide to avoiding plagiarism, which is posted in Canvas. Following this excellent guide will protect you against verbatim and mosaic plagiarism, inadequate and uncited paraphrase, uncited quotations, and using material from other student's work.

Lecture Schedule for GEO 331, Fall 2019; M, W, F Time 10:00, WILK 235

Date	Class	Inst.	Topic	*Assignment due* or activity
Week 0				
W, Sep 25	1	C*	Intros, syllabus, est. "other" life, critical thinking	No assignment due
F, Sep 27	2	F	History of astrobiology, the Drake equation	Ch 1; *Assignment (Assign) 1 due (C)*
Week 1 **New moon field trip (TBA as weather/viewing permits)**				
M, Sep 30	3	F	From stardust to planets, the abodes of life	Ch 2 to page 21; *Assign 2 due (F)*
W, Oct 2	4	F	The Milky Way, star types	Ch 2, 3, pages 22 to 31 Handout; *Assign 3 due (F)*
F, Oct 4	5	C	Making elements (nucleosynthesis)	In class activity; No assignment due
Week 2 **Meet with instructor by October 9. Paper topic and brief outline due October 11.**				
M, Oct 7	6	C	Defining life and the attributes of life	Ch 3 Origin of Life to end, p. 31-43; *Assign 4 due (C)*
W, Oct 9	7	C	Is it alive or not? Will we recognize alien life?	Baross handout in Canvas, *Assign 5 (C); Office visit.*
F, Oct 11	8	F	Electromagnetic spectrum	Quiz #1; No assignment due. *Short paper outline due.*
Week 3				
M, Oct 14	9	C	The origin of life and rise of complex life	Ch 4; Chen 2006, Stueken 2013; *Assign 6 due (C)*
W, Oct 16	10	C	The tree of life; strategies for living	Tree of life in Ch 5; *Assign 7 due (C)*
F, Oct 18	11	C	The bare necessities and pre-biotic chemistry	In class activity only; No assignment due
Week 4 **Field trip to nearby pond**				
M, Oct 21	12	F	Biosignatures on Earth (fossils and chemistry)	Ch 3; *Assign 8 due (F)*
W, Oct 23	13	F	Planetary and stellar spectra; elemental abundance	Ch 7; *Assign 9 due (F)*
F, Oct 25	14	F	Earth history, the moon, meteors, comets	Ch 3
Week 5 **First draft of paper due November 1.**				
M, Oct 28	15	C	The extremes of life (environmental conditions)	Extremophiles Ch 5; *Assign 10 due (C)*
W, Oct 30	16	C	The extremes of life (species)	Papers in Canvas; *Assign 11 due (C)*

F, Nov 1	17	C	Panspermia, lithopanspermia	*Full paper outline draft due*. In class discussion
Week 6				
M, Nov 4	18	C	Photosynthesis and the rise of oxygen	Quiz #2; no assignment
W, Nov 6	19	F	Snowball Earth and runaway greenhouses	Ch 4; *Assign 12 due (F)*
F, Nov 8	20	F	Extinctions and persistence	Ch 4; *Assign 13 due (F)*
Week 7				
M, Nov 11			**Veterans Day – no class**	
W, Nov 13	21	F	Mars planetary history and Mars meteorites	Ch 6; *Assign 14 due (F)*
F, Nov 15	22	F	Potential for life on Mars	Ch 6; *Assign 15 due (F)*
Week 8 **Final draft of paper due November 22**				
M, Nov 18	23	F	Potential for life on ice-covered moons	Ch 6; No assignment due
W, Nov 20	24	F	Exoplanet detection method	Ch 7 *Assign 16 due (F)*
F, Nov 22	25	F	Galactic habitable zones	*Paper due.Assign 17 due (F)*
Week 9				
M, Nov 25	26	C	Search for extraterrestrial life	Quiz #3; No assignment due
W, Nov 27	27	C	Messages sent, messages received	Ch 7; *Assign 18 due (C)*
F, Nov 29			**Holiday – no class**	
Week 10				
M, Dec 2	28	C	The Fermi Paradox, existential risk	Ch 7; *Assign 19 due (C)*
W, Dec 4	29	F	Rare Earth and Earth's legacy	Ch 8; *Assign 20 due (C)*
F, Dec 6	30	CF	Wrap up, review for the final	No assignment due
Week 11				
M, Dec 9			**Final exam this week**	

* denotes lead lecturer; C = Colwell; F = Fisk