Term Information

Effective Term	Autumn 2023
Previous Value	*Autumn 2022*

Course Change Information

What change is being proposed? (If more than one, what changes are being proposed?)

We propose a re-numbering of Astronomy 1141 to 2141. The revised course, Astronomy 2140, is proposed for inclusion in the Origins and Evolution Theme. It will also continue to satisfy the legacy Foundations course requirement, although it is not eligible for the new Foundations (which require 4 credits and a lab).

What is the rationale for the proposed change(s)?

Astronomy 2141 was one of the 10 initial courses submitted in the approved proposal for the Origins and Evolution Theme. To create Astronomy 2141, we extensively revised the prior Foundations 1141 course, and we view 2141 as a logical replacement for 1141. The proposed changes include a number of elements that require a 2000-level designation rather than a 1000-level designation. These include the requirement that the natural sciences Foundation be satisfied, readings, problem sets, in-class discussions, field trips, a variety of assessment tools, and a greater emphasis on interdisciplinary questions.

What are the programmatic implications of the proposed change(s)?

(e.g. program requirements to be added or removed, changes to be made in available resources, effect on other programs that use the course)?

The new course will satisfy the GE Themes, but not the foundations. The precursor course was not a prerequisite for other courses, and neither is the proposed 2141 course. We therefore expect no net impact on other programs. Neither course requires a laboratory, so there is no change in required laboratory facility needs.

Is approval of the requrest contingent upon the approval of other course or curricular program request? No

Is this a request to withdraw the course? No

General Information

Course Bulletin Listing/Subject Area	Astronomy
Fiscal Unit/Academic Org	Astronomy - D0614
College/Academic Group	Arts and Sciences
Level/Career	Undergraduate
Course Number/Catalog	2141
Previous Value	*1141*
Course Title	Life in the Universe
Transcript Abbreviation	Life in Universe
Course Description	We will learn about scientists' ongoing quest for answers to some of the most fundamental human questions: How did life originate on Earth? Is there life on other worlds? Are we alone in the universe? What is the long-term future of life in the universe?
Previous Value	*Potential for life elsewhere in the universe, based on discovery of extra-solar planets and nature of life on Earth; search strategies for such life.*
Semester Credit Hours/Units	Fixed: 3

Offering Information

Length Of Course	14 Week, 12 Week
Flexibly Scheduled Course	Never
Does any section of this course have a distance education component?	No

Grading Basis	Letter Grade
Repeatable	No
Course Components	Lecture
Grade Roster Component	Lecture
Credit Available by Exam	No
Previous Value	**Yes**
Previous Exam Types	*Departmental Exams*
Admission Condition Course	No
Off Campus	Never
Campus of Offering	Columbus, Lima, Mansfield, Marion, Newark, Wooster
Previous Value	*Columbus, Mansfield*

Prerequisites and Exclusions

Prerequisites/Corequisites	Completion of the Natural Science GE Foundation, Math at the level of 1050 or higher, or permission of instructor.
Previous Value	
Exclusions	Not open to students with credit for 1141
Previous Value	
Electronically Enforced	No

Cross-Listings

Cross-Listings

Subject/CIP Code

Subject/CIP Code	40.0201
Subsidy Level	General Studies Course
Intended Rank	Freshman, Sophomore, Junior, Senior

Requirement/Elective Designation

General Education course:

Physical Science; Origins and Evolution

Previous Value

General Education course:

Physical Science

Course Details

Course goals or learning objectives/outcomes

- The course goals and learning objectives are taken from those required for all new GE courses, as well as those specific to the Origins and Evolution Theme. The goals are below, and the learning objectives are given in the attached ELO questionnaire.
- General GE Goal 1: Successful students will analyze an important topic or idea at a more advanced and in-depth level than the foundations. (abridged)
- General GE Goal 2: Successful students will integrate approaches to the theme by making connections to out-of-classroom experiences with academic knowledge or across disciplines and/or to work they have done or will do in other courses. (abridged)
- Origins and Evolution GOAL 1: Analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.
- Origins and Evolution GOAL 2: Integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and to other course work they have done or will do. (abridged)
- Origins and Evolution GOAL 3: Appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.
- Origins and Evolution GOAL 4: Understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

Previous Value

- *Investigating the basic facts, principles, theories, and methods of modern science as practiced in astrobiology.*
- *Learning about the basic observations of the natural world that underlie our inquiry into the nature of life in the universe.*
- *Learning important events in the history of astronomy, biology, geology, and chemistry, and how they have caused our views of life in the universe to change with time.*
- *Explaining the role of modern technology in our investigation of the Galaxy and the search for life beyond the Earth.*

Content Topic List

- The emergence and nature of life on the Earth
- The potential for life on other planets in our Solar System
- The search for habitable worlds and life around other stars in our Galaxy.

Previous Value

- *Scientific basis for study of life in the Universe.*
- *History of modern science, foundations of astrobiology, search for origins of life*
- *Relationships between science, society, and the search for life in the universe*
- *Exploration of the potential implications of the discovery of life elsewhere in the Universe*

Sought Concurrence

No

Attachments

- Ast1141Sp20Syl.pdf: prior course syllabus

  (Syllabus. Owner: Pinsonneault,Marc Howard)
- Astronomy_2141_Syllabus_proposed.docx: Proposed New Syllabus

  (Syllabus. Owner: Pinsonneault,Marc Howard)
- Astronomy_2141_OE elo_questionnare_proposed.docx: ELO questionnaire

  (GEC Model Curriculum Compliance Stmt. Owner: Pinsonneault,Marc Howard)

Comments

- This is one of four astronomy courses being transitioned from the 1000 level to the 2000 level. *(by Pinsonneault,Marc Howard on 08/30/2022 01:07 PM)*

Workflow Information

Status	User(s)	Date/Time	Step
Submitted	Pinsonneault,Marc Howard	08/30/2022 01:12 PM	Submitted for Approval
Approved	Weinberg,David Hal	08/30/2022 02:14 PM	Unit Approval
Approved	Vankeerbergen,Bernadette Chantal	09/27/2022 01:39 PM	College Approval
Pending Approval	Cody,Emily Kathryn Jenkins,Mary Ellen Bigler Hanlin,Deborah Kay Hilty,Michael Vankeerbergen,Bernadette Chantal Steele,Rachel Lea	09/27/2022 01:39 PM	ASCCAO Approval

Astronomy 2141: Life in the Universe
Template Syllabus

3 contact hours per week, lecture format with in-class participation and questions

GE Theme: Origins and Evolution

Course Material

Are we alone in the universe? This is one of the oldest questions of humanity. As little as 30 years ago we know of only one planetary system, our own. Today we know of nearly 5000 planetary systems around other stars, many completely different than your own. The explosion of knowledge about planets around other stars has moved the question "Are we alone?" from the realm of speculation and science fiction into the forefront of astronomical research in the 21^{st} century, emerging as a question that can be answered scientifically. The hunt for other Earths has emerged as one of the primary research questions driving the planning for new observatories and space missions in the 21^{st} century. Life in the Universe is an introduction to Astrobiology for non-science majors. The topics covered in this course lie at the intersections between Astronomy, Chemistry, Biology, and the Earth and Planetary sciences. We will learn about scientists' ongoing quest for answers to some of the most fundamental human questions: How did life originate on Earth? Is there life on other worlds? Are we alone in the universe? What is the long-term future of life in the universe?

The course covers three primary topics:

The emergence and nature of life on the Earth

The potential for life on other planets in our Solar System

The search for habitable worlds and life around other stars in our Galaxy.

The course will begin with a brief introduction to modern science and astronomy and ends with a brief discussion of the long-term future of life on Earth and in the Universe in general.

Course Topics

The course will cover the following topics. The week-by-week breakdown is approximate.

Introduction: Imagining Other Worlds

- Introduction and overview, how we have imagined extraterrestrial life in human cultures, the scale of the cosmos.
- The depths of geological and cosmic time, the nature of matter, light, and energy.

Life on Earth

- The structure of Earth's interior and atmosphere, the geological history of the Earth.
- Atmospheric climate regulation and climate change, the definition of life, evolution by natural selection, the structure of cells and nature of cellular metabolism.
- The chemistry of life; DNA, RNA, and heredity, and extremophile organisms.
- Abiogenesis (the origin of life from non-life), and the history of life on Earth from its earliest forms to the present day, mass extinction events and planetary impacts

Life in the Solar System

- Overview of our Solar System, comparison of the terrestrial planets, the giant planets and their moons.

- The requirements for life in a planetary context, the planet Mars, and the searches for past and present-day life on Mars.
- The potential for life Jupiter's moon Europa and Saturn's moons Enceladus and Titan. The habitable zone of the Sun.

Life in the Universe

- The properties of the stars, the demographics of stars in the solar neighborhood, and the life cycle of stars
- Habitable Zones around stars, the discovery and characterization of exoplanetary systems.
- Searches for other Earths with biosignatures, the definition of intelligent life, and the Drake Equation
- The search for extraterrestrial intelligence (SETI), interstellar travel and colonization, and the Fermi Paradox
- Convergent evolution and the possible nature of extraterrestrial life, the possible scientific and societal impacts of detecting life elsewhere, first-contact protocols if we find intelligent life.

Prerequisites

The prerequisites for this course are completion of the Natural Science GE Foundation and math at the level of Math 1050. The math in this course will not go beyond simple algebra, but there will be equations and geometrical or mathematical reasoning in some lectures and assignments. The math itself will not be difficult, but the concepts will be challenging, and *translating concepts into equations and back is one of the major things you will learn during the course*.

Course Materials

The subject matter in the course benefits from a variety of potential sources. *OpenStax Astronomy* by Fraknoi, Morrison, Wolff: https://openstax.org/details/books/astronomy is a useful general resource. *Basin and Range* (John McPhee) is a valuable source on geology. *Microcosmos* (Lynn Margulis & Dorian Sagan), serves a similar purpose for the study of evolution. *Packing for Mars: The Curious Science of Life in the Void* (Mary Roach), covers the realities and complexities of space travel. *The Planet Factory: Exoplanets and the Search for a Second Earth* (Elizabeth Tasker), is a resource for understanding planets around other stars. Finally, *Rare Earth: Why Complex Life is Uncommon in the Universe* (Peter Ward and Donald Brownlee), is a synthesis work about life in the universe. Selected portions of these texts are the basis for both in-class discussions and the homework assignments below. We emphasize texts that are open-source when possible; failing that, they are available on reserve, or affordable via standard outlets such as Amazon.

Field Trips. We will take advantage of the resources here at Ohio State to learn more about the geological, climatological, and biological history of Earth and the search for life beyond Earth. We plan to take virtual or actual field trips to the Orton Geological Museum, the Museum of Biological Diversity, the Byrd Polar Research Center, and the Arne Slettebak Planetarium. Please pay attention to different meeting places for the class on these days.

Assessments, exams, and grading.

In Class Exercises and Mini-quizzes. To encourage you to engage with the material and to give you an opportunity to earn points for effort and participation, many classes will feature "in-class" exercises. Discussion with your classmates is encouraged (and sometime required). Brief in-class mini-quizzes will test major concepts introduced in that week in advance of the main quiz. There are 6 in total, typically one in each of the two weeks preceding a major quiz. The lowest scoring mini-quiz will be dropped. In-class exercises and short mini-quizzes comprise 30% of the total grade.

Homework. Homework will be assigned at regular intervals, with a total of 6 assignments during the semester. The lowest-scoring homework will be dropped. Homework assignments involve answering questions related to text readings and short essays about selected topics and total 20% of the grade.

Quizzes and Final Exam. Depending on the size of the course, and the goals of the instructor, we adopt a mixture of short answer or multiple-choice questions on these tests. Study guides are distributed in advance of the exams, and the questions are drawn from the list of study guide questions. Three in class quizzes, covering the three major sections (Life on Earth, in the Solar System, and in the Universe) comprise 10% of the grade each, with a cumulative final exam being 20% of the total.

Students with Disabilities

Students with disabilities that have been certified by Office of Student Life Disability Services (SLDS) will be appropriately accommodated and should inform the instructor as soon as possible of their needs. SLDS is located in 98 Baker Hall, 113 W. 12th Avenue; Phone: 292-3307, VRS: 429-1334; (slds.osu.edu). We will rely on SLDS to verify the need for accommodation and work with them to develop appropriate strategies. Students with disabilities who have not previously contacted SLDS are encouraged to do so by visiting the SLDS website and requesting an appointment. Please take care of this well in advance of the exams, as processing the paperwork takes time.

Academic Misconduct

It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term academic misconduct includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the Code of Student Conduct (studentconduct.osu.edu).

Learning Objectives

General Education Learning Goals & Outcomes

The Curriculum Committee of the College of Arts & Sciences requests that syllabi of all GE courses list the goals and learning objectives for the relevant category of the GEC.

Goals: Successful students will:

1. Analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.

2. Integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and by making connections to work they have done in previous classes and/or anticipate doing in the future.

3. Appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

4. Understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

Expected Learning Outcomes, Origins & Evolution Theme

Successful students will be able to:

1.1 Apply their understanding of scientific methods to quantitative calculations.

1.2 Engage in critical and logical thinking about the origins and evolution of the universe, physical systems, life on earth, humanity or human culture.

2.1 Identify, describe, and synthesize approaches to or experiences of origins and evolution questions in different academic and non-academic contexts.

2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.

3.1 Illustrate their knowledge of the time depth of the universe, physical systems, life on earth, humanity or human culture by providing examples or models.

3.2 Explain scientific methods used to reconstruct the history of the universe, physical systems, life on earth, humanity or human culture and specify their domains of validity.

3.3 Engage with current controversies and problems related to origins and evolution questions.

4.1 Describe their knowledge of how the universe, physical systems, life on Earth, humanity or human culture have evolved over time.

4.2 Summarize current theories of the origins and evolution of the universe, physical systems, life on earth, humanity or human culture

Astronomy 1141, Spring Semester, 2020

MWF 1:50-2:45 PM
Room: Hitchcock Hall 324

Professor: Marc Pinsonneault
Office: 4043 McPherson Lab
Office Hours: Tu 9:00-10:30 AM
or by appointment
Email pinsonneault.1@osu.edu

TA: Chris Cappiellllo
Office: PRB M2025
Office Hours: Th 2-4
or by appointment
Email cappiello.7@osu.edu

Grading and Exam Summary:

- *9 in-class mini-quizzes*. These exercises, given roughly every Friday, will be based on questions discussed in class and will represent ~13% of the grade (20 POINTS). The lowest score is dropped. Excused absences will be omitted from the average; there are no make-up mini-quizzes.
- *3 in-class exams*. These will be ~58% of the total grade (90 POINTS) and are in multiple-choice format. Makeup exams require a medical excuse and will be in short answer format.
- *Final Exam.* ***The Cumulative Final Exam is Tuesday, April 28 from 4:00-5:45***, and it is ~29% of the total grade (45 POINTS).

Course Outline

Week 1 1/6 – 1/10: Introduction. Imagining Other Worlds. Our Place in Space.
Week 2 1/13-1/17: Matter and Energy. Our Place in Time. The Earth We Stand On. **Miniquiz.**
Week 3 1/22-1/24: The Greenhouse Effect. The Carbon Cycle. **Miniquiz.**
Week 4 1/27 - 1/31: Climate Change. What is Life? Cells and Metabolism. **Miniquiz.**
Week 5 2/3 - 2/7: The Chemistry of Life. DNA and RNA. **QUIZ 1 2/7**
Week 6 2/10 - 2/14: The Origin and Evolution of Life. **Miniquiz.**
Week 7 2/17 - 2/21: Impacts and Contingency. Formation of the Solar System. Terrestrial Planets. **Miniquiz.**
Week 8 2/24 - 2/28: Jovian Planets and Tides. Life in the Solar System. **Miniquiz.**
Week 9 3/2 – 3/6: Life in the Solar System. **QUIZ 2 3/6**
SPRING BREAK 3/9 – 3/13 NO CLASS
Week 10 3/16 – 3/20: The Properties of Stars. The Habitable Zone. **Miniquiz.**
Week 11 3/23 – 3/27: Finding Exoplanets. Other Stars, Other Worlds. Dynamic Formation. **Miniquiz.**
Week 12 3/30 – 4/3: Finding Other Earths. The Present and Future of Planet Hunting. **Miniquiz.**
Week 13 4/6 – 4/10: SETI. Intelligent Life. **QUIZ 3 4/10.**
Week 14 4/13 – 4/17: Interstellar Travel. The Fermi Paradox. Life as We Don't Know It.
Week 15 4/20: Course Summary.

Detailed Summary

Course Objectives

Astronomy 1141 is a General Education (GE) Physical Science course in the Natural Science category. The goals of courses in this category are for students to understand the principles, theories, and methods of modern science, the relationship between science and technology, the implications of scientific discoveries and the potential of science and technology to address problems of the contemporary world.

The expected learning outcomes for GE courses in the Natural Science category are as follows:

1. Students understand the basic facts, principles, theories and methods of modern science.
2. Students understand key events in the development of science and recognize that science is an evolving body of knowledge.
3. Students describe the interdependence of scientific and technological developments.
4. Students recognize social and philosophical implications of scientific discoveries and understand the potential of science and technology to address problems of the contemporary world.

Astronomy 1141 will meet these expected outcomes by:

1. Investigating the basic facts, principles, theories, and methods of modern science as practiced in astrobiology.
2. Learning about the basic observations of the natural world that underlie our inquiry into the nature of life in the universe.
3. Learning important events in the history of astronomy, biology, geology, and chemistry, and how they have caused our views of life in the universe to change with time.
4. Explaining the role of modern technology in our investigation of the Galaxy and the search for life beyond the Earth.

Course Organization

Astronomy 1141 meets three days per week for 3 hours of lecture. Lectures are Monday, Wednesday, and Friday at 1:50-2:45 PM in Room 324 Hitchcock Hall. **Attendance is required**. The lectures are your primary source of course content, and the exams and quizzes will be based on the lectures and in-class discussions.

Weekly Mini-Quizzes

Weekly mini-quizzes quizzes are short *in-class* quizzes designed to test your comprehension of the material covered during the week, with three of them for each main quiz. These are largely drawn from the in-class discussion topics, and are designed to be brief (<15 minutes). Solutions will be posted to Carmen. Collectively, they account for ~**13%** of your course grade. Note, however, that if you miss a mini-quiz, it cannot be made up. Excused absences will simply be omitted from the average: e.g. if you have one excused absence, your 20 points will be allocated based on the best 7/8 of the ones that you took, rather than the best 8/9.

In-Class Exams

There will be three in-class exams. The exams will be held at the normal class time on these dates:

In-Class Exam 1: **Friday, February 7**
In-Class Exam 2: **Friday, March 6**
In-Class Exam 3: **Friday, April 10**

You will have the entire time to take the exams which cover the material in the lectures since the previous exam. All of the questions are drawn from study guides that are distributed in class and posted on Carmen. All in-class exams will be 30-question **closed-book, closed-notes, closed-Internet, multiple-choice** tests. Collectively, they account for **~58%** of the grade.

Makeup exams are only offered by advance arrangement with the professor, except for legitimate, documented emergencies. If you are away on official University-sponsored activities (ROTC, sports, band, etc.), please get a letter from your coach, director, etc. **in advance** of the exam. Exams must be made up by the Wednesday following the missed exam date. All make-up exams will be administered at the OSU Testing Center.

Final Exam

The Final Exam is on **Tuesday, April 28 from 4:00-5:45pm in HI 324**. Attendance is mandatory. The final will be worth **~29%** of your grade. It will be a mix of multiple choice questions (similar in format to the quizzes above), and of an essay tying together themes from the course. Essay topics will be distributed in advance, and you will be able to choose which of the topics you write about. **No makeup final will be offered.** Students who miss the final exam will be given an incomplete (I) with an alternative grade equal to getting a zero on the final, and have to make it up the following Semester to avoid the alternative grade. In keeping with University policy, early finals will **not** be available for persons wishing to depart early for the summer.

Students with Disabilities

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New Theme Course Submission Form

Astronomy 2141: Life in the Universe

Submitted for approval for the new theme "Origins and Evolution"

Background Statement

Astronomy 1141, Life in the Universe, has been taught as a Natural Sciences GE course since 2009. Traditionally, Astronomy has numbered all of its GE classes at 1000-level and used 2000-level and above for calculus-based courses designed for astronomy & astrophysics majors. Under the revised GE, we are numbering Foundation courses at 1000-level and renumbering the Theme courses to 2000-level. These courses, including Life in the Universe, have always required the application of algebra and geometry to understanding the physical universe and solving astrophysics problems. Our renumbering partly acknowledges that students have always regarded these courses as challenging, and it also recognizes the higher level of presentation, discussion, and assignments that are feasible now that students will have completed the Natural Sciences Foundation requirement before taking them. We have also adjusted several assignments to require deeper engagement.

In Astronomy 2141, we start by examining the one world we know that has life, the Earth, and discuss how life operates on Earth, theories of the origin of life, the history of life on Earth as revealed through its fossil record and phylogenetic tree, and the role of evolution. We describe the structure of the Earth and its atmosphere and consider the features of Earth that stabilize its climate and make long-lasting life possible, such as the greenhouse effect and the carbon-silicate cycle, as well as large-scale changes to that stability such as the oxygenation of Earth's atmosphere and anthropogenic climate change. Next, we examine the origin and evolution of our solar system, considering possible habitable times for rocky worlds in the past, present, or future. Tidal locking and tidal heating of rocky worlds, the development of atmospheres, and the evolution of the Sun are all important considerations. One of the most exciting developments of the past 30 years has been the discovery of thousands of exoplanets outside of our solar system, which has enormous implications for the possibility of life elsewhere in the Universe. We discuss the technology and techniques that made these discoveries possible and look at the new frontiers in this area of research.

The 3-credit hour course is comprised of class meetings involving lecture, small-group discussions, and in-class exercises and questions. Readings from well-researched popular science books form a key part of the course, allowing the students to engage more fully with the nature of scientific discovery in all its complexity through the voices of scientists. The selections from the five books cover a wide range of topics. We begin with *Microcosmos*, focusing on its chapters on the origin of life, the evolution of eukaryotic cells with nuclei and mitochondria, and the appearance of multi-cellar life. Next, *Basin and Range* uses the geology of the American West as a launching pad for discussing how we learned to understand the history of the Earth and importance of plate tectonics. Having considered life on Earth, we now go to space and consider other possible locations in the solar system, such as Mars, Europa, and Titan, where life may also have arisen and discuss future exploration of these worlds. *Packing for Mars* explores the issues that arise from long spaceflight, both from a psychological (how do humans adjust to the void of space) and a biological (what does free floating do to the human body) standpoint. As we learn about Earth in comparison to other rocky worlds, the readings from *Rare Earth* offer the perspective that these differences may make these worlds fundamentally uninhabitable for intelligent life. *The Planet*

Factory describes the solar systems around other stars that we have discovered and how their environments may make them more or less habitable. The in-class questions and homework assignments play central roles in achieving the ELOs and assessing that achievement. For example, we do brightness and luminosity calculation, and equilibrium temperature as individual assignments. Then we apply these principles to useful sample cases: the atmosphere of the moon Titan, and the habitable zone around Proxima Cen b. Some topics are reflective: for example, the value judgements required to infer the total number of civilizations currently in the Galaxy that we infer in the Drake Equation. Some are review, helping students synthesize recently covered material and prepare for exams.

In the remainder of this form, instructions and examples have been set in blue type while the new responses are set in black type.

Overview

Each category of the General Education (GE) has specific learning goals and Expected Learning outcomes that connect to the big picture goals of the program. Expected Learning Outcomes (ELOs) describe the knowledge or skills students should have by the end of the course. Courses in the GE Themes must meet the ELOs common for **all** GE Themes and those specific to the Theme, in addition to any ELOs the instructor has developed specific to that course.

The prompts below provide the goals of the GE Themes and seek information about which activities (discussions, readings, lectures, assignments) provide opportunities for students to achieve the ELO's associated with that goal. The answer should be concise and use language accessible to colleagues outside of the submitting department or discipline. The specifics of the activities matter—listing "readings" without a reference to the topic of those readings will not allow the reviewers to understand how the ELO will be met. However, the panel evaluating the fit of the course to the Theme will review this form in conjunction with the syllabus, so if readings, lecture/discussion topics, or other specifics are provided on the syllabus, it is not necessary to reiterate them within this form.

Goals and ELOs shared by *all* Themes

Goal 1: Successful students will analyze an important topic or idea at a more advanced and in-depth level than the foundations. In this context, "advanced" refers to courses that are e.g., synthetic, rely on research or cutting-edge findings, or deeply engage with the subject matter, among other possibilities.

Goal 2: Successful students will integrate approaches to the theme by making connections to out-of-classroom experiences with academic knowledge or across disciplines and/or to work they have done in previous classes and that they anticipate doing in future.

For each of the ELOs below, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The ELOs are expected to vary in their "coverage" in terms of number of activities or emphasis within the course. Examples from successful courses are shared on the next page.

ELO 1.1 Engage in critical and logical thinking.	This course requires students to engage in critical and logical thinking to understand how we know the geological and biological history of the Earth, the nature of potentially habitable worlds in the solar system, and the discovery and characterization of exoplanets and the possible detection of life on other worlds. For example, in homework and in field trips, students will engage with evidence for how life first arose on the Earth and how it became more complex, first through the development of more complex one-celled animals and then through the development of multi-celled life. This will then be applied (in homework, discussions, and exams) to inferences about how the lessons of life on Earth apply elsewhere in the Universe. The questions of what is meant by "life" and what is meant by "intelligent life" also require careful consideration. Students will be presented with examples of things that have some or all of the criteria to be considered alive and will discuss in small groups what the definition of life is and whether entities such as viruses and computer viruses should be considered alive or not or As a class, we will then discuss the conclusions of the small groups and end up with a working definition of life. A similar exercise will be done for intelligent life, including the crucial question of how constrained we are by our imagination in how intelligence will appear.
ELO 2.1 Identify, describe, and synthesize approaches or experiences.	Understanding the origin and history of the Earth, its life and the possible origin of life elsewhere requires a mix of approaches. Students will work with 1) laboratory measurements, 2) observational results, and 3) theoretical work. They will also be challenged to synthesize these approaches to understand how the evolution of life on Earth has affected its observable properties and how this might affect the search for life on other planets. For example, students will consider the phylogenetic tree for the relationships between organisms, based on laboratory genetic sequencing as well as their own observations in nature for the structural similarities that also can indicate related organisms. They will explore the nature of gravity through laboratory measurements on its strength, observations of falling objects and orbits, and theoretical understanding of its behavior as an inverse-square law with inertial masses. This combination guides the student to understand how gravity can be applied across the Universe, including in exoplanet systems far from the Earth. Their work on the interactions between matter and light includes insights from the laboratory on radiation and the formation of spectra and observations of the solar spectrum and the spectra of the Earth, Mars, and Venus. The synthesis of this knowledge yields theoretical predictions for the appearance of Earth's spectrum throughout its history and identification of possible biosignatures that can be detected from other worlds.

ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative work, building on prior experiences to respond to new and challenging contexts.	The in-class questions and assignments provide regular opportunities for self-assessment, as students can determine how well they understood the material. The quantitative in-class exercises become more complex during the semester, as concepts are repeated in novel situations. Students begin by understanding the phase diagram (how pressure and temperature determine whether a substance is solid, liquid, or gas) of water, calculating the escape speed of the Moon, and calculating equilibrium temperature of Mars as separate exercises. Next, they calculate the escape speed and the equilibrium temperature of Titan and consider the phase diagram of methane in a single exercise. Finally, they do the same for the planet detected orbiting the closest star to the Sun to see whether it could have liquid water on the surface and be a possible location for life to originate. In the first class of this course, students are asked to give their best guesses for the numbers that go into the Drake equation, such as the fraction of planets that are habitable, the number of planets per star, and the lifetime of intelligent communicating civilizations. Throughout the course, these factors are linked to the lectures and class activities, such as identifying greenhouse effects and tidal heating as ways to increase the fraction of planets with liquid water. Later in this course, students are asked again to give their more informed estimates of the numbers for the Drake equation. We discuss these numbers as a class and put the median values in to determine the class' estimate of the number of civilizations in the Galaxy. This provides an opportunity for the students to assess how much they have learned. For in-class discussions near the end of the course, we ask the students to combine what they have learned in this course with creative expression by considering what culture could be like on a world very different than ours. This not only emphasizes the ways that exoplanets can be different than Earth, but also encourages the students ponder what about human culture is responsive to the properties of Earth. The exams and homework questions also provide an opportunity for self-assessment about their success in understanding arguments presented in the readings and their synthesis of the material to answer the exam questions.

Goals and ELOs of the GE Theme: Origins and Evolution

GOAL 1: Analyze the origins and evolution of natural systems, life, humanity, or human culture at a more advanced and in-depth level than in the Foundations component.

GOAL 2: Integrate approaches to the origins and evolution of natural systems, life, humanity, or human culture by making connections to their own experiences and by making connections to work they have done in previous classes and/or anticipate doing in the future.

GOAL 3: Appreciate the time depth of the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

GOAL 4: Understand the origins and evolution of natural systems, life, humanity, or human culture, and the factors that have shaped them over time.

Enter your ELOs in the Table below, editing and removing rows as needed. There should be at least one ELO for each goal, and they should be numbered to correspond to the goal (e.g., ELO1.1 is the first ELO for Goal 1, ELO 2.2 would be the second ELO for the second goal).

For each ELOs, please identify and explain course assignments, readings, or other activities within this course that provide opportunity for students to attain the ELO. If the specific information is listed on the syllabus, it is appropriate to point to that document. The number of activities or emphasis within the course are expected to vary among ELOs. Examples from successful courses are shared below.

ELO 1.1 Apply their understanding of scientific methods to quantitative calculations.	Quantitative calculations form a key part of many of the in-class exercises or homework, providing students with key information to test their hypotheses and draw conclusions. For example: Why is Earth is in the habitable zone, where water is in liquid form, and where are the habitable zones around other stars? We begin by discussing the properties of light in lectures – the inverse square law, blackbody radiation, and how the emitted energy and peak flux depend on temperature. Students then can compute – in class discussions, homework, and on exams – increasingly sophisticated inferences about how much sunlight we receive in Earth orbit, what temperature you would need to be to emit that much light, and what kind of light you would emit. This leads in turn to a discussion of the greenhouse effect, and later in the class to one where students can compute where the habitable zone is in stars with different energy outputs. Another quantitative topic is the retention of atmospheres. After a general framework presented in lecture, students compute (in class) a worked example for Titan, the moon of Saturn, and what sort of atmosphere we might expect it to be able to retain. We then generalize this into a broader picture of the key ingredients – planet mass, temperature, and molecular mass – that determine atmosphere retention, and the interplay with geological activity.
ELO 1.2 Engage in critical and logical thinking about the origins and evolution	Throughout this course, students will be presented with the evidence for how we know important facts not

of the universe, physical systems, life on earth, humanity, or human culture	directly observed, such as the age of the Earth, the timeline for life on the Earth, and the existence of exoplanets, and are asked to think critically and logically about the consequences of this evidence. For example, in lectures students will learn the evidence that supports the idea that all life on Earth descended from a common ancestor and evaluate the implications of this for how easy it is for life to arise. This includes in-class and homework exercises about inferring ages from radioactive decay. A staff member from the Museum of Biological Diversity will give a presentation on evolution and the evidence in current organisms of the natural variation that natural selection can work on. We supplement this with a field trip to the Chadwick Arboretum, examining gingko trees as an example of persistence, identifying plants from different clades, and finding thornless relatives to the rose and the cactus as an example of the convergent evolution of thorns. Students will then reason through the implications of the history of life on Earth for the detection of life elsewhere in the Universe. This will begin by asking them what an alien visitor to the Earth would have witnessed if they came to the planet at a random time during our history, and then using that example to infer what we might expect if we studied planets around stars with a wide range in ages.
ELO 2.1 Identify, describe, and synthesize approaches to or experiences of origins and evolution questions in different academic and non-academic contexts.	To study the origin and evolution of life and humans on Earth and what that means for the existence of life and intelligent life, students will use several different approaches. In this course, students will need to be able to gather together key information from distinct areas. The general principles of physics dictate the properties of light and the orbits of planets. We use the tools of astronomy to infer the observed properties of stars and planets and to detect exoplanets. Geology of the Earth and solar system bodies is crucial for understanding the interplay between planet size, age and habitability. The history of life, as inferred on Earth, is our basic template for life elsewhere. These approaches will be synthesized in lectures, reading and homework to show how laboratory experiments, observations of nature, and theoretical work can be used to understand the origin and evolution of solar systems and of life. We also include popular culture descriptions of alien life and contrast them with our current scientific understanding.
ELO 2.2 Demonstrate a developing sense of self as a learner through reflection, self-assessment, and creative	The in-class questions and assignments provide regular opportunities for self-assessment, as students can determine how well they understood the material. The quantitative in-class exercises become more complex

work, building on prior experiences to respond to new and challenging contexts.	during the semester, as concepts are repeated in novel situations. Students begin by understanding the phase diagram (how pressure and temperature determine whether a substance is solid, liquid, or gas) of water, calculating the escape speed of the Moon, and calculating equilibrium temperature of Mars as separate exercises. Next, they calculate the escape speed and the equilibrium temperature of Titan and consider the phase diagram of methane in a single exercise. Finally, they do the same for the planet detected orbiting the closest star to the Sun to see whether it could have liquid water on the surface and be a possible location for life to originate. In the first class of this course, students are asked to give their best guesses for the numbers that go into the Drake equation, such as the fraction of planets that are habitable, the number of planets per star, and the lifetime of intelligent communicating civilizations. Throughout the course, these factors are linked to the lectures and class activities, such as identifying greenhouse effects and tidal heating as ways to increase the fraction of planets with liquid water. In the final class of this course, students are asked again to give their more informed estimates of the numbers for the Drake equation. We discuss these numbers as a class and put the median values in to determine the class' estimate of the number of civilizations in the Galaxy. This provides an opportunity for the students to assess how much they have learned. For in-class discussions near the end of the course, we ask the students to combine what they have learned in this course with creative expression by considering what culture could be like on a world very different than ours. This not only emphasizes the ways that exoplanets can be different than Earth, but also encourages the students ponder what about human culture is responsive to the properties of Earth. The exams and homework questions also provide an opportunity for self-assessment about their success in understanding arguments presented in the readings and their synthesis of the material to answer the exam questions.
ELO 3.1 Illustrate their knowledge of the time depth of the universe, physical systems, life on earth, humanity or human culture by providing examples or models.	The lengthy history of the Earth, the early appearance of simple life and the late appearance of intelligent, complex life is crucial evidence for evaluating the possibility of life elsewhere. Students will also consider the age of the Galaxy and its successive stellar generations when thinking about the number of habitable worlds.

	For example, in lectures we present the array of tools that we have for inferring ages in the Earth, the Solar System, and for other stars. Each of these situations has different regimes of applicability; for example, the active Earth erases much of its history, while meteorites give a fossil record of the very early solar system. Ages of other stars can be robustly inferred in some cases but are difficult in others. We reinforce these points with in-class exercises and readings. For a class discussion, students will compare their estimates of the lifetime of civilizations to the age of the Milky Way as a key component of the Drake Equation. *Microcosmos* presents the evidence for critical inflections in the history of life on Earth and students demonstrate mastery through their answers to the homework questions. *Basin and Range* presents the geological arguments that finally established the great age of the Earth and students demonstrate mastery through their answers to the homework questions.
ELO 3.2 Explain scientific methods used to reconstruct the history of the universe, physical systems, life on earth, humanity or human culture and specify their domains of validity.	Students learn about these methods through lectures, in-class exercises and discussion, and homework readings, and reveal their knowledge in responses in homework and exams. For example, students are given the number of uranium and lead atoms in a zircon crystal and asked to determine the age of the rock for an in-class exercise. They also assess what age they have determined and why it is less than the true age of the Earth. In other contexts they will be asked to infer the lifetimes of stars to determine whether they are long-lived enough to host planets, as we believe that that it may take planets longer to form, or live longer to establish, than the maximum ages of some stars.
ELO 3.3 Engage with current controversies and problems related to origins and evolution questions.	The origin of life on the Earth and its possible appearance elsewhere are questions at the forefront of astrobiology research. There are ample opportunities for students to engage with these controversies. In lectures we present the controversy over what the earliest convincing evidence of life on Earth is, and the possible mechanisms for abiogenesis (the creation of the first life on Earth). For an in-class exercise, students will first be presented with examples of things that have some or all of the criteria to be considered alive and will discuss in small groups what the definition of life is and whether the things presented to them (in particular viruses and computer viruses) should be considered alive or not. As a class, we will then discuss the conclusions of the small groups and end up with a working definition of life.

	One of our texts, *Rare Earth,* presents the counter-argument to the more common idea that intelligent life may arise in one of the many, many planets that exist in our Galaxy by noting the rare combination of properties that make Earth habitable. We will assess the current status of that argument in lecture, noting where recent advances have reinforced or weakened the arguments. Another text, *The Planet Factory,* discusses the many currently unsolved problems in the formation of solar systems and planets, such as the origin of Super Earths. It also shows the ways that planets that lie in the temperate zone around their stars might not be habitable while other planets could have special niches where life might arise.
ELO 4.1 Describe their knowledge of how the universe, physical systems, life on Earth, humanity or human culture have evolved over time.	We rely on quantitative assessment, in the form of our quizzes and final exam, to test their knowledge of the evolution of stars, planets and life over time.
ELO 4.2 Summarize current theories of the origins and evolution of the universe, physical systems, life on earth, humanity or human culture.	We rely on quantitative assessment, in the form of our quizzes and final exam, to test their knowledge of theoretical explanations for the formation of stars, planets and life and their evolution over time.