

- Instructor:** Prof. Axel Brandenburg (email: Axel.Brandenburg@Colorado.edu)
 Office on East Campus: SPSC N-216 (LASP), Phone: (303) 735-7738
- Office hours:** D230 (Duane, second floor): Wednesdays 11–12,
 X590 (X-wing of JILA): Mondays 2:30–3:30, or by appointment
- Course Times:** Mon., Wed., & Fri., 10–10:50 am
- Location:** Duane, Room G1B20
- Course web page:** D2L and http://lcd-www.colorado.edu/~axbr9098/teach/ASTR_2040
- Teaching Assistant:** Erika Zetterlund (email: Erika.Zetterlund@Colorado.edu)
 Office hours Wed. 1–2 in D239, by appointment,
 and in Astronomy Help Room (AHR, D142) Wed. 2–4

SUMMARY

Introduces the scientific basis for the possible existence of life elsewhere in the universe. Includes origin and evolution of life on Earth and the search for evidence of life in our solar system, especially Mars and Jupiter’s moon Europa. Discusses the conditions necessary for life and whether those might arise on planets around others stars.

COURSE GOALS

At the end of the course, you should be able to:

- describe the basic building blocks of life as we know it,
- explain how life may have originated on Earth,
- judge what are the prospects of finding life elsewhere in our solar system,
- find and work with scientific papers to educate your own judgement.

COURSE MATERIAL

Primary textbook (required):

- *An Introduction to Astrobiology*, by David A. Rothery, Iain Gilmour, & Mark A. Sephton (Cambridge University Press, 2011):

Recommended reading (see library):

- *Astrobiology: An Introduction*, by Alan Longstaff (CRC Press, 2014), contains more detailed explanations
- *Life in the Universe*, by Jeffrey O. Bennett & Seth G. Shostak (Pearson, San Francisco, 2017), is entertaining and contains many other aspects, but is also expensive

GRADING

The final grade will be assembled from the following components:

6 Homework Sets	25%
Quizzes	20%
Midterm Exam	20%
Final Exam	25%
In-Class Engagement	10%
Total	100%

SCHEDULE OF TOPICS

The dates listed here for each set of topics are approximate. Please follow the course web page on Desire2Learn and http://lcd-www.colorado.edu/~axbr9098/teach/ASTR_2040/ for lecture notes, teaching material, and any updates.

Week 1: Introduction to astrobiology (Aug 28)

History of astrobiology. Early observations of Mars. The four corner stones of astrobiology. Darwinian evolution. Why carbon? Why water? The building blocks of life as we know it.

Week 2: Studying the origin of life (Sep 4)

Biomarkers of past life. Bottom up versus top down. Organic matter in the Universe. Synthesis of organic molecules. Urey/Miller experiment. The Murchison meteorite.

Week 3: Delivery of building blocks (Sep 11)

Did the biomolecules come from outer space? Delivery of water and organic material by comets. Was homochirality a prerequisite for or a consequence of life? Chirality of an independent genesis? Panspermia.

Week 4: From chemistry to biology (Sep 18)

Metabolism first versus replication first. The RNA world. Autotrophs and hydrothermal vents. The three domains of life. LUCA, the last common universal ancestor.
→ *Quiz #1 on Sep 20 (Wednesday)*

Week 5: Origin of life on Earth (Sep 25)

When greenhouse gases can be useful. What is a habitable planet? Habitable zones. The carbon cycle on Earth. Plate tectonics and volcanism. Comparison with Venus. The great oxidation event.

Week 6: Evidence for early life on Earth (Oct 2)

Sources of water on Earth. Earth's early atmosphere. Oceans by 4.4Gyr? Geological record: what do the oldest rocks tell us? Significance of the ^{13}C isotope. Cambrian explosion of life.

Week 7: Life under extreme conditions (Oct 9)

Temperature. Radiation. pH. Salinity. Desiccation. Pressure. Oxygen.
→ *Midterm exam on Oct 13 (Friday) and Fiske Planetarium on Oct 11 (Wednesday)*

Week 8: Mars (Oct 16)

Early Exploration. The Viking probes of the 1970s. Evidence for past & present water. Impact craters and active gullies. Results from recent missions.

Week 9: Mars (cont'd, Oct 23)

Evolution of Martian atmosphere. Possible significance of hydrogen on early Mars. Martian meteorites. Planetary protection.

Week 10: Satellites of Jupiter (Oct 30)

Tidal heating of satellites. Evidence for a liquid ocean on Europa. Europa's surface. Hydrothermal systems & life on Europa. Lessons from Lake Vostok.

Week 11: Satellites of Saturn (Nov 6)

Titan's atmosphere. Rich organic chemistry. Far from chemical equilibrium. Origin of nitrogen. Thermal structure of the atmosphere. Titan's surface. Lakes & precipitation.

Week 12: Outer solar system's bodies (Nov 13)

Organic chemistry on comets & results from Rosetta. Biomolecules on asteroids & future missions.
→ *Quiz #2 on Nov 15 (Wednesday) and Fiske Planetarium on Nov 13 (Monday)*

Week 13: Searching for Life on Exoplanets (Nov 27)

The first discovery of exoplanetary systems. Exoplanet diversity. How to find biospheres on exoplanets?

Week 14: Exoplanet atmospheres (Dec 4)

Investigating Exoplanets from Earth and space.

Week 15: (Dec 11)

SETI, the Search for Extraterrestrial Intelligence. Communication with extraterrestrials. The Arecibo message. Fermi paradox: where is everybody? Constraints on interstellar space travel.

HOMEWORK SETS

There will be six homework assignments distributed throughout the semester. Please turn in your homework at the *beginning* of class. Your five best ones count toward your final grade.

MIDTERM EXAM & QUIZZES

There will be two quizzes (probably on Sep 20 and Nov 15). The midterm exam is planned for Oct 13. The Final Exam is on Saturday, Dec 16, 4:30–7:00.

IN-CLASS ENGAGEMENT

Attendance is important, because frequently the class will separate either individually or into small groups. In these break-out sessions, you will work out some interesting implication, or draw some useful conclusion, from the lecture material. No written answers need to be submitted; just verbal discussion of the outcomes.

The grade for this component is essentially “try” or “not-try.” In addition, your responses to clicker questions will be recorded and used for grading. Thus, your regular attendance is important to get your 1/10 of the total grade. In-class engagement is also demonstrated by asking questions, answering questions that someone else has raised, and/or participating actively in the break-out sessions.

ACADEMIC INTEGRITY

All students at CU Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct will be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion).

For this course, I encourage you to discuss the assignments and topics with your fellow students. However, everything that is written up and submitted must be your own independent work. If you do collaborate with other students, a good time to split off from the group is when you start to write up your answers. If someone were to ask you questions about your work, you should be able to explain everything about how & why you did it the way you did.

STUDENTS WITH DISABILITIES

If you qualify for accommodations because of a disability, please submit to me a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities, and they can be contacted at 303-492-8671, by e-mail (dsinfo@colorado.edu), or on the web (disabilityservices.colorado.edu).

RELIGIOUS OBSERVANCES

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. If you have religious obligations that result in schedule conflicts, please contact me in the first two weeks of class to make alternate arrangements.

DISCRIMINATION AND HARASSMENT

CU Boulder is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. CU Boulder will not tolerate acts of discrimination or harassment based upon protected classes or related retaliation against or by any employee or student. For purposes of this CU Boulder policy, “protected classes” refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550.

CLASSROOM BEHAVIOR

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student’s legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.

September 27, 2017, Revision: 1.27