Geomicrobiology

ERTH-491-01, GEOL-572-04, GEOB-589-01, GEOC-572-01, HYD-572-01, HYD-572D-01
Fall, 2019

Lectures: M/W/F 10:00-10:50 AM, Room 20, Martin Spear Building

Instructor: Daniel Jones, Ph.D.
Contact: daniel.s.jones@nmt.edu
Office: 314 Material Science and Engineering Complex (MSEC)
Office hours: M 11:00 AM-12:00 PM, Th 2:00-3:00 PM, or by appointment.
Virtual office hours: T 7:00-8:00 PM (Zoom/Skype or similar), or by appointment

Course overview: Welcome to Geomicrobiology! Microorganisms play an enormous role in the geological and geochemical processes that shape our planet's surface. Because of their ubiquity and metabolic diversity, microbes control crucial chemical transformations in the modern world, and their evolution over the past 3.5 billion years has forever altered Earth's landscape. In this course, we will start by exploring the basis for those interactions, including redox geochemistry, microbial metabolism, the diversity of microbial lifestyles, and microbe-mineral interactions. Later in the course we will consider the consequences of microbial processes for global biogeochemical cycling and for the co-evolution of life and the Earth. Other topics will include molecular and phylogenetic methods for exploring the microbial world, pollutant biodegradation, microbial paleobiology, and astrobiology.

Place in Curriculum: This course is an elective for most undergraduate and graduate degrees offered in the Earth and Environmental Science Department, and is required for the PhD in Earth and Environmental Science with Dissertation in Geobiology.

Course Learning Outcomes: By the end of this course, students will have developed an appreciation for the diversity of life on our planet, and be able to explain how microorganisms impact geochemical processes in diverse natural and engineered systems. Students will be able to apply principles of thermodynamics to predict energetically-favorable metabolisms in a given environmental context; describe how microbial activity is used in engineering processes such as pollutant biodegradation and metal mining; and explain how microbial evolution has impacted Earth's biosphere and geosphere through time, and how to recognize evidence for that life in the rock record. Students will demonstrate that they are able to integrate and synthesize material from the primary literature in writing assignments.

Program Learning Outcomes: Learning outcomes for undergraduate and graduate degrees in Earth and Environmental Science: https://nmt.edu/academics/ees/Outcomes.php

Prerequisites: Previous college coursework in biology is a prerequisite for this course. If you have a limited biology background and have arranged with me to take the course anyway, you should expect to work harder than usual to catch up on material that would have been covered in the prerequisite course. You may find it useful to develop working collaborations with students who have complementary biology or geology expertise to help you get up to speed.

Field trip: There will be two field trips during the course, one of which will be on a weekend. Attendance and participation in field trips is required, and in the event of a schedule conflict, we will find alternative activities. Details will be provided in lecture. Students taking the Distance Education (DE) section of this course will have the option of an alternative activity (Winogradsky columns) in place of the field trips.

Course website: Canvas course website, http://learn.nmt.edu

Readings:

Required text: *Brock Biology of Microorganisms (15th ed.), by Madigan et al.* Brock Biology is an excellent reference and is the microbiology text of choice for many physical scientists interested in microorganisms. If you don't want to purchase it, a copy is placed on reserve at the Skeen Library and used copies of earlier editions are also available. If you choose to use an earlier edition, you will need to translate the page number for reading assignments.

Other required readings: Additional readings will be taken from the scientific literature, and are listed in the course schedule. Electronic versions will be made available through the course webpage.

Skeen library reserve: The following references are placed on reserve at the Skeen library

- *Brock Biology of Microorganisms* by Madigan et al. A copy of both the 15th and 12th editions are on reserve.
- *Introduction to Geomicrobiology* by Konhauser (2007). This text is another good geomicrobiology reference, and you might find it useful both for reinforcing course concepts as well as when researching for your review paper or proposal.
- *Ehrlich's Geomicrobiology* by Ehrich, Newman, and Kappler (2015). This text is another excellent geomicrobiology reference, and is a more advanced than Konhauser (2007). A copy of both 5th and 6th edition are on reserve.
- *Fundamentals of Geobiology* by Knoll (2012). This is another excellent reference for many topics in geomicrobiology and geobiology, and is especially relevant for global biogeochemistry and deep time topics.

Writing: Effective communication to both a broad audience and to your scientific peers is paramount for a successful career. Students will be asked to write one paper for this course, either a review paper or a proposal. A more detailed description of the writing assignment is given below, and additional details will be provided in class. I will also assign additional writing as part of the homework.

Grade basis:

Homework	25%
Proposal or review paper	25%
Midterm exams	25%
Final exam	10%
Presentations	5%
Class participation	10%

Exams: We will have two midterms and a final exam that will cover lecture and reading material.

Homework: During the term, six homework assignments will be posted online. Assignments will be made available after class, and will generally be due in class the following week. Homework will take the form of problem sets (for example, balancing redox reactions and calculating free energy) as well as critical analysis of primary literature.

Class participation: Starting mid-way through the term, we will have periodic class discussions of primary literature. Primary literature refers to articles from peer-reviewed journals that present results of original research, and are the main mechanism by which scientific results are communicated. The purpose of these discussions is to critically evaluate the assumptions, results, and implications of different studies that represent significant milestones in geomicrobiology. Part of your grade will be based on participation in group discussions, which includes the following:

- Before each discussion, all members of the class are expected to contribute a question or comment to facilitate discussion of the assigned article, via an online forum (on Canvas).
- Active participation during the in-class discussion, which includes reading the assigned article, and asking questions and responding to prompts by discussion leaders.
- Leading in-class discussions: depending on discussion format, students may be asked to lead informal in-class discussions following small group activities.

Presentations: You will give two short "lightening talks" during the term, a "microbe of the week" presentation and a lightening talk about your proposal or review paper. Presentations will last approximately five minutes, and details will be discussed in class. Breaking down a complex topic into a brief presentation that is appropriate and easily digestible for your target audience is a tall order, but one that is important for your success as a scientist, whether you are talking to a scientific peer, neighbor, state senator, or funding agency representative.

Proposal or Review Paper: The final paper for the class will be a proposal or a review paper on a topic of your choice, due on the last day of class. Graduate students are required to write a proposal, and undergraduates can choose between a proposal and a review paper.

Proposal: For the proposal, you will identify a compelling research avenue in the field of geomicrobiology, and propose questions, hypotheses, and methods to address the issue in an original way. The proposal should be 7-10 pages (12 point font, 1 inch margins, single-spaced), including figures but not references, and should be formatted as an NSF-style proposal. You are encouraged to incorporate original figures that you have drafted yourself. No budget is needed, nor is a realistic budget a requirement. (Within reason! No sample return trips to Europa!)

Review paper: For the review paper, you will review a geomicrobiological process or group of geobiologically-important organisms. The review should be 7-10 pages (12 point font, 1 inch margins, single-spaced), including figures but not references, and you are encouraged to incorporate original figures that you have drafted yourself. You should expect to cite a minimum of 20 articles from the peer-reviewed literature.

Please note the due dates for the paper/proposal topic, abstract/summary, outline and bibliography, and partial draft on the class schedule. **You are also welcome to turn in a draft to me at any point up until the week before the final paper is due.** If you choose to do this (and I highly recommend it!), do not expect to receive immediate feedback from me, but within three days is reasonable. Drafts may be rough, but should be reasonably well written and not contain egregious spelling errors and typos. (The last date to turn in a draft for feedback is 11/27/2019.)

You are encouraged to take advantage of the resources available at the Writing and Communication Lab, which offers qualified tutors for graduate and undergraduate students to improve writing skills (https://www.nmt.edu/academics/class/center.php).

Examples of potential paper topics:
(but, you are encouraged to come up with your own idea!)

The deep marine biosphere
Microbial formation of phosphatic mineral deposits
Bioremediation of acidic mine drainage
Chemosynthetic communities at whale falls
Cave geomicrobiology
Adaptations to microbial life at extremely acidic pH or at extremely high temperatures
Animal-bacterial symbioses at hydrothermal vents or cold seeps
Microbiology of mercury methylation
Bacterial photosynthesis in the ocean
Evolution of photosynthesis
Nitrogen fixation
Microbial role in granite weathering
Carbonate formation at methane seeps
Perchlorate-reducing bacteria
Trichloroethylene (TCE) biodegradation
Ammonia oxidation in wastewater
Extracellular polymeric substances in microbial mats
Arsenate respiration
Microbial chromium transformation
Carbonate precipitation in stromatolites
And many others… you are encouraged to discuss your idea with me before you start (especially if you decide on a paper topic that is not on this list)

Late work and extra credit policy: Homework assignments may be turned in up to a week late at a 25% penalty. No credit will be given for homework assignments turned in more than a week late. Writing assignments will be penalized 10% each day they are late. In other words, if you turn in your final review paper or proposal two days late, the maximum score you can expect to receive is 80%.

No extra credit is available. I will look over any exam or homework questions you think are not graded correctly and adjust your score as appropriate, but I will not negotiate your final grade for even a fraction of a point. If you are having trouble in class for academic or any other reasons and are concerned about your grade, please see me early on so we can discuss how you can improve your understanding and performance.

Academic Honesty: New Mexico Tech's Academic Honesty Policy for undergraduate and graduate students is found in the student handbook, which can be found at: https://www.nmt.edu/academicaffairs/docs/policies/NMT_Student_Handbook_2018-19.pdf. You are responsible for knowing, understanding, and following this policy.

Reasonable Accommodations: New Mexico Tech is committed to protecting the rights of individuals with disabilities. Qualified individuals who require reasonable accommodations are invited to make their needs known to the Office of Counseling and Disability Services (OCDS) as soon as possible. To schedule an appointment, please call 575-835-6619.

Counseling Services: New Mexico Tech offers mental health and substance abuse counseling through the Office of Counseling and Disability Services. These confidential services are provided free of charge by licensed professionals. To schedule an appointment, please call 575-835-6619.

Respect Statement: New Mexico Tech supports freedom of expression within the parameters of a respectful learning environment. As stated in the New Mexico Tech Guide to Conduct and Citizenship: "New Mexico Tech's primary purpose is education, which includes teaching, research, discussion, learning, and service. An atmosphere of free and open inquiry is essential to the pursuit of education. Tech seeks to protect academic freedom and build on individual responsibility to create and maintain an academic atmosphere that is a purposeful, just, open, disciplined, and caring community."

Title IX Reporting: Sexual misconduct, sexual violence and other forms of sexual misconduct and gender-based discrimination are contrary to the University's mission and core values, violate university policies, and may also violate state and federal law (Title IX). Faculty members are considered "Responsible Employees" and are required to report incidents of these prohibited behaviors. Any such reports should be directed to Tech's Title IX Coordinator (Dr. Peter Phaiah, 20D Brown Hall, 575-835-5187, titleixcoordinator@nmt.edu). Please visit Tech's Title IX Website (www.nmt.edu/titleix) for additional information and resources.

Language on New Mexico Tech policies from https://www.nmt.edu/academicaffairs/policies.php

Class schedule: Geomicrobiology (ERTH-491-01/GEOL-572-04/GEOB-589-01/GEOC-572-01/ HYD-572-01/HYD-572D-01), M/W/F 10:00-10:50, Spear 20

Be aware that both lecture materials and readings may be subject to change as the semester progresses

Week 1		**Course introduction and tree of life**	
M	8/19	Course overview and introduction to geomicrobiology *Reading: Brock Ch. 1*	
W	8/21	The universal tree of life *Reading: Brock Ch. 1 part IV; Pace (2006); Spang and Ettema (2016)*	
F	8/23	Overview of the Bacteria, Archaea, and Eukarya *Reading: Brock Ch. 2*	
Week 2		**Chemical energy and redox**	
M	8/26	Oxidation reduction reactions and chemical energy *Reading: Brock Ch. 3 p. 78-85 and handouts*	HW #1 assigned, redox reactions, free energy
W	8/28	Chemical energy continued *Reading: Amend and LaRowe (in press)*	
F	8/30	Chemical energy continued; microbial energy generation *Reading: Brock Ch. 3*	
S	***8/31***	***Field trip: Valles Caldera and Jemez Springs, depart from MSEC at 8:00 am***	
Week 3		**Microbial energy generation**	
M	9/2	No class - Labor Day	
W	9/4	Microbial diversity in sulfur springs and other extreme environemnts of the Valles Caldera area - microscopy activity (meet in Jones Annex) *Reading: Brock Ch. 1 p. 11-17; Szynkiewicz et al. (2012)* ***If you are unable to attend class this day, please arrange to make up the microscopy activity***	
F	9/6	Field trip recap; continue microbial energy generation *Reading: Szynkiewicz et al. (2012); Brock Ch. 3*	Due in class: HW #1 HW #2 assigned, metabolic diversity of sulfur springs
Week 4		**Microbial energy generation**	
M	9/9	Chemosynthesis and autotrophy; Winogradsky column presentations and predictions *Reading: relevent sections of Brock Ch. 14 and 15 - try not to get get bogged down in the details of these chapters, focus on getting an overview of microbial energy sources and modes of energy generation*	
W	9/11	Chemosynthesis and autotrophy *Reading: relevent sections of Brock Ch. 14 and 15*	
F	9/13	Anaerobic respiration and fermentation *Reading: relevent sections of Brock Ch. 14 and 15*	
Week 5		**Microbial energy generation**	
M	9/16	Photosynthesis and phototrophy *Reading: relevent sections of Brock Ch. 14 and 15*	Due in class: HW #2
W	9/18	Photosynthesis and phototrophy *Reading: relevent sections of Brock Ch. 14 and 15* ***EES Departmental seminar, Dr. Jennifer Macalady, 4:00 pm, MSEC 101***	

F	9/20	Photoheterotrophy *Reading: Beja et al. (2000) and News Focus by Pennisi; Kolber et al. (2000); Karl (2002). Come prepared to discuss these articles in class.*	**Literature discussion:** Beja et al. (2000), Kolber et al. (2000), Karl (2002)
Week 6		**Contaminants and bioremediation**	
M	9/23	No class - GSA week	
W	9/25	Sulfide mineral oxidation and acid mine drainage *Reading: Brock Ch. 22*	
F	9/27	**Midterm exam 1 (covers material from weeks 1-5)**	
Week 7		**Bioremediation and microbe-mineral interactions continued**	
M	9/30	Sulfide mineral oxidation and acid mine drainage continued *Reading: TBA*	HW #3 assigned, bioremediation
W	10/2	Microbial mercury cycling and methylmercury *Reading: Brock Ch.21 part III; Perspective by Poulain and Barkay (2013)* ***Topic for final proposal/paper due (in class, 10/2/2019)***	
F	10/4	Organic biodegredation *Reading: Selected articles for HW3*	
Week 8		**Microbe-mineral interactions continued**	
M	10/7	Respiration of minerals *Optional reading: Gralnick and Newman (2007)*	Due in class: HW #3
W	10/9	Finish mineral respiration; biomineralization *Optional reading: Brock Ch. 2.8; Schulz and Schulz (2005)*	HW #4 assigned, primary literature review
F	10/11	Sulfur bacteria and microbial sulfur cycling *Reading: Pfeffer et al. (2012); News and Views by Reguera; Come prepared to discuss these articles in class.*	**Literature discussion:** Pfeffer et al. (2012)
Week 9		**Selected topics and case studies: TBA (based on student interest)**	
M	10/14	TBA (student interest) *Reading: TBA*	
W	10/16	TBA (student interest) *Reading: TBA*	
F	10/18	No class - academic holiday	
Week 10		**Selected topics and case studies: TBA (based on student interest)**	
M	10/21	TBA (student interest) *Reading: TBA* ***Outline and draft summary/abstract of proposal/review paper due (in class, 10/21/2019)***	Due in class: HW #4
W	10/23	Viruses in the environment *Reading: Philippe et al. (2013); News and Views by Pennisi (2013). Come prepared to discuss these articles in class.*	**Literature discussion:** Philippe et al. (2013)
F	10/25	Guest lecture - Dr. Thomas Kieft *Reading: TBA*	
Week 11		**Selected topics and case studies**	
M	10/28	**Midterm exam 2 (covers material from weeks 6-10)**	

W	10/30	Phylogenetic analysis, horizontal gene transfer, and the tree of life *Reading: Brock Ch. 13 section III; Doolittle (1999); Reviews/News and Views by Attar (2016), McInerney and O'Connell (2017)*	HW #5 assigned, phylogenetics
F	11/1	Phylogenetic analysis, horizontal gene transfer, and the tree of life *Reading: Brock Ch. 13 section III; Doolittle (1999); Reviews/News and Views by Attar (2016), McInerney and O'Connell (2017)*	
Week 12		**Early life and evolution of the biosphere**	
M	11/4	Early evidence for life *Optional reading: Brock Ch. 13, section I*	Due in class: HW #5
W	11/6	Early evidence for life continued (remote lecture) *Reading: TBA*	
F	11/8	Stromatolites and microbial mats *Reading: Reid et al. (2000); Come prepared to discuss this article in class. Additional readings TBA*	HW #6 assigned, biogenicity **Literature discussion:** Reid et al. (2000)
Week 13		**Early life and evolution of the biosphere**	
M	11/11	Microfossils and microbial paleobiology *Reading: Schopf et al. (2002), Brasier et al. (2002), Schopf et al. (2018); Come prepared to discuss these articles in class.* ***First 3 pages of proposal/review paper due (in class 11/11/2019)***	**Literature discussion:** Schopf and Brasier
W	11/13	Rise of oxygen 1 *Reading: Kump (2008)*	Due in class: HW #6
		EES Departmental seminar, geomicrobiology of lava caves, Dr. Diana Northup 4:00 pm, MSEC 101	
F	11/15	Class field trip: microbialites and astrobiology analogues in the Quebradas	
Week 14		**Early life and evolution of the biosphere**	
M	11/18	Guest lecture - Dr. Linda DeVeaux *Reading: TBA*	
W	11/20	Rise of oxygen 2 *Reading: Konhauser et al. (2002); Come prepared to discuss this article in class.*	**Literature discussion:** Konhauser et al. (2002)
F	11/22	Class presentations; rise of oxygen 3 *Reading: TBA*	
Week 15		**Astrobiology**	
M	11/25	Origin of life *Reading: excerpts from Lane (2009) and Hazen (2005)*	
W	11/27	Origin of life continued; start astrobiology and life elsewhere *Reading: excerpts from Lane (2009) and Hazen (2005)* ***Optional: last day to turn in proposals/review paper drafts for feedback (in class, 11/27/2019)***	
F	11/29	No class - Thanksgiving holiday	
Week 16		**Astrobiology**	
M	12/2	Class presentations; astrobiology and life elsewhere *Reading: excerpts from Lane (2009) and Hazen (2005)*	
W	12/4	Class presentations; astrobiology and life elsewhere *Reading: TBA*	
F	12/6	Astrobiology and life elsewhere ***Proposal/review paper due (in class 12/6/2019)***	

Final exam (will be scheduled between 12/7/2019-12/13/2019)