ESCI 4801: Geomicrobiology

Spring, 2014

Lectures: M, W 2:30-3:45 PM, Pillsbury Hall, Room 209

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Office hours: Tu & F 1:00-2:00 PM, 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 and 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 include molecular and phylogenetic methods for exploring the microbial world, microbial-induced mineral dissolution and formation, pollutant biodegradation, microbial paleobiology, and astrobiology.

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 one or possibly two weekend field trips to local mineral springs. Attendance and participation in field trips is required, and we will make sure to accommodate everyones schedules. The field trip locations are either on campus or in relatively close proximity. Details will be provided in lecture.

Course website: Moodle course website, https://ay13.moodle.umn.edu

Readings:

Required text: *Brock Biology of Microorganisms (13th ed.), by Madigan et al.* Brock Biology is an excellent reference and is the text of choice for many geomicrobiologists. A copy is placed on reserve at the Walter Library. Used copies of the 11th or 12th editions are also available, but you will need to translate the page number for reading assignments.

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

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

- *Brock Biology of Microorganisms* by Madigan et al. (2012). A copy of both the 13th and 11th 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 and proposal.
- *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. A hard copy has been placed on reserve, and an online version is also available through the UMN library webpage.

Writing: Effective communication to both a broad audience and to your scientific peers is paramount for a successful scientific 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 assignments is given below, and additional details will be provided in class.

Grade basis:

Homework	30%
Participation	10%
Proposal/Review paper*	25%
Midterm	20%
Final	15%

*Each student decides whether to write a review paper or a proposal

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

Homework
During the term, five 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.

Participation in class discussions
Starting mid-way through the term, we will begin to incorporate 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 Moodle).
- Active participation during the in-class discussion, which includes reading the assigned article, and asking questions and responding to prompts by the discussion leader.

- Leading in-class discussions: each student will be designated to lead or co-lead a discussion at one point during the semester. Discussion leaders will present the paper, and then informally facilitate a class discussion.
    - Discussion leaders: prepare a ~15 minute presentation (chalk talk with handouts or powerpoint) to introduce the paper, put it in context, describe major results and discussion points, and add a few comments of your own about what you thought was interesting, what could have been done better/differently, etc.
    - Expect the class to ask questions during your presentation, and at the end of your talk, prompt the class for questions and comments, and lead a discussion.
    - Use the questions/comments posted by the class to facilitate discussion, either as discussion prompts and/or as inspiration to target your discussion

Proposal or 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 free 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 your 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), and you should cite a minimum of 15 articles from the peer-reviewed literature.

Please note the due dates for review paper/proposal topics, draft summary/abstract and outlines on the class schedule. **You are also welcome to turn in a rough draft to me at any point 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 3 days is reasonable.

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

Geomicrobiology of whale falls
The deep marine biosphere
Microbial formation of phosphatic mineral deposits
Bioremediation of sulfide mine drainages
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

Geomicrobiology of gold
Microbial activity associated with natural nuclear reactors
Extracellular polymeric substances in microbial mats
Arsenate respiration
The geomicrobiology of rock varnish
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)

The fine print:

Attendance and Etiquette: Regular attendance and participation in discussions is expected, and is included in your grade. Cell phones absolutely must be switched off. Please be prompt and ready to start at the designated class time. If you arrive late, your entrance will disrupt the lecture and disturb those students who did arrive on time.

Academic integrity: Academic integrity is essential to a positive teaching and learning environment. All students enrolled in University courses are expected to complete coursework responsibilities with fairness and honesty. Failure to do so can result in disciplinary action. The University Student Conduct Code defines scholastic dishonesty, which includes plagiarizing and cheating on assignments or examinations. A student responsible for scholastic dishonesty can be assigned a penalty including an "F" or "N" for the course. For additional information on university policy pertaining to scholastic dishonesty, see the Student Conduct Code and FAQs at the links below:
http://regents.umn.edu/sites/default/files/policies/Student_Conduct_Code.pdf
http://www1.umn.edu/oscai/integrity/student/index.html

Disabilities statement: It is university policy to provide, on a flexible and individual basis, reasonable accommodations to students who have disabilities that may affect their ability to participate in course activities or to meet course requirements. Students with disabilities are encouraged to contact the professor.

Grades: Following University of Minnesota policy, the major letter grades in this course are defined as follows: A, achievement that is outstanding relative to the level necessary to meet course requirements; B, achievement that is significantly above the level necessary to meet the course requirements; C, achievement that meets the course requirements in every respect; D, achievement that is worthy of credit even though it fails to meet fully the course requirements; F, achievement not worthy of credit or a course not completed and no agreement with the instructors about assigning an Incomplete. For additional information, please refer to:
http://policy.umn.edu/Policies/Education/Education/GRADINGTRANSCRIPTS.html

The average overall score in the course after all points are accounted for will determine the C+/B- boundary. If you score above the overall average, you will get at least a B-; if you score below the average, you will get at most a C+. The other divisions and subdivisions will be based on the distribution of the scores around the average (i.e., based on the standard deviation around the average score). If the class average is above 80%, no curve will be applied, and letter grades will be defined using the standard scale (>90%, A; 80-90%, B, etc., with boundaries for +/- grades defined at 3.33% cutoffs: e.g. 80-83.33% B-, 86.66-89.9%, B+).

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 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 your performance.

You can take the course S-N if you choose and it fits with your degree requirements. **A grade of S represents achievement that is satisfactory and is equivalent to a C- or better**; a grade of N represents achievement not worthy of credit or a course not completed and no agreement with the instructors about assigning an Incomplete.

Missing class: You must notify us in advance of any travel plans for university-sponsored events (athletics or other activities) that will interfere with scheduled course work, including exams. If you are sick and miss scheduled course work, you must bring in medical verification of your illness. Students will not be penalized for absence during the semester due to unavoidable or legitimate circumstances. Such circumstances include verified illness, participation in intercollegiate athletic events (see Administrative Policy: *Intercollegiate Athletic Events during Study Day and Finals Weeks: Twin Cities*, which prohibits intercollegiate athletic competition during study and finals week except under certain circumstances), subpoenas, jury duty, military service, bereavement, and religious observances. Such circumstances also include activities sponsored by the University if identified by the senior academic officer for the campus or his or her designee as the basis for excused absences. Such circumstances do not include voting in local, state, or national elections. For complete information, please see: http://policy.umn.edu/Policies/Education/Education/MAKEUPWORK.html.

If you have any physical or learning needs that might impact your learning and evaluation in this course, please let us know as soon as you can so I can make any necessary arrangements with you. The University has a multitude of resources so don't hesitate to let us know.

Late work: 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 proposal two days late, the maximum score you can expect to receive is an 80%.

Schedule of lecture topics and assignments: **Be aware that both lecture materials and readings are subject to change as the semester progresses**

Week 1		**Introduction, course overview**	
W	1/22	Course overview and introduction to geomicrobiology *Reading: Brock Ch. 1-2*	
Week 2		**Microbes and microbial metabolism**	
M	1/27	The universal tree of life; overview of the bacteria, archaea, and eukarya *Reading: Brock Ch. 2 part II, Ch. 3; Pace (2006)*	
W	1/29	Chemical energy and redox potential *Reading: Brock appendix 1, Ch. 4 p. 92-105*	HW #1, redox reactions, free energy
S	***2/1***	***Field trip 1: Iron springs***	
Week 3		**Microbial metabolism cont.**	
M	2/3	Light microscopy, microbial diversity in iron springs ***If you are unable to attend class this day, make arrangements with me to make up the microscopy*** *Reading: Brock Ch. 2 p. 25-31, p. 36-37*	Due in class: HW #1
W	2/5	Microbial energy generation *Reading: Brock Ch. 4, p. 92-105*	HW #2, Microbial metabolic diversity of iron springs
Week 4		**Microbial energy generation**	
M	2/10	Chemosynthetic electron transport *Reading: Brock Ch. 13 part II and III, Ch. 14 part II*	Due in class: HW #2
W	2/12	Photosynthetic electron transport *Reading: Brock Ch. 13 part I, III*	
Week 5		**Microbial energy generation cont.**	
M	2/17	Electron transport continued; begin phototrophy *Reading: Brock Ch. 13 part I*	
W	2/19	Phototrophy *Readings: Beja et al. (2000) and News Focus by Pennisi; Karl (2002); TBA*	Literature discussion
Week 6		**Bioremediation**	
M	2/24	Acid mine drainage; mercury *Readings: 24.5, 24.7-8; TBA*	HW #3, Bioremediation
W	2/26	Biodegradation of organics *Readings: Brock Ch. 24.9-24.10; Lovley (2001); Gossett (2002); TBA*	
Week 7		**Respiration of solids, extremophiles**	
M	3/3	How microbes respire minerals *Readings: Newman et al. (2001), Lovley (2001); TBA* **Topic for review paper due (in class, 3/3/2014)*	Due in class: HW #3
W	3/5	Extremophiles *Readings: TBA*	
Week 8		**Midterm week, start methods**	
M	3/10	Start methods, culturing, lab tour (not on the exam) *Readings: Ch. 4.1-4.3; Ch. 22.1-2*	
W	3/12	**MIDTERM EXAM (in class)**	Midterm

---------- Spring break, 17 March 2014 to 21 March 2014 ----------

Week 9		**Methods cont.**	
M	3/24	Start methods; culture independent analysis *Reading: Brock Ch. 22*	
W	3/26	Culture independent analysis; start phylogenetics *Reading: Brock Ch. 22*	
Week 10		**Methods cont.; sulfur cycling**	
M	3/31	Phylogenetic analysis and horizontal gene transfer *Reading: Xiong et al. (2000); Doolittle (1999)*	**HW #4, Phylogenetics**
M	***3/31***	****Topic for final proposal/paper due (in class, 3/31/2014)***	
W	4/2	Sulfur bacteria and microbial sulfur cycling *Reading: Brock Ch. 13.8, 17.4, 17.18-19; Pfeffer et al. (2012); Reguera (2012) News and Views*	**Literature discussion:** Pfeffer et al. (2012)
S/Su		*Optional field trip to iron springs?*	
Week 11		**TBA, based on student interest**	
M	4/7	Geomicrobiology of caves	**Due in class: HW #4**
W	4/9	Viruses in the environment *Reading: Philippe et al. (2013); Pennisi (2013) News and Views*	**Literature discussion:** Philippe et al. (2013)
S/Su		*Optional field trip to iron springs?*	
Week 12		**Microbe mineral interactions**	
M	4/14	Hydrothermal vents and methane seeps *Readings (optional): Kelley et al. (2005); TBA*	
M	***4/14***	****Outline and draft summary/abstract of proposal/review paper due (in class, 4/14/2014)***	
W	4/16	Stromatolites and microbial mats *Readings: Reid et al. (2000)*	**Literature discussion;** Reid et al. (2000)
Week 13		**Microbial evolution and deep time**	
M	4/21	Microfossils and microbial paleobiology *Readings: Schopf et al. (2002), Brasier et al. (2002), Schopf et al. (2012)*	HW #5 assigned **Literature discussion;** Schopf and Brasier
W	4/23	Rise of oxygen 1 *Readings: Kump (2008)*	
Week 14		**Microbial evolution and deep time cont.**	
M	4/28	Rise of oxygen 2 *Reading: Konhauser et al. (2002); Grice et al. (2005); TBA*	Due in class: HW #5 **Literature discussion 2;** Konhauser et al. (2002) **Literature discussion 1;** Grice et al. (2005)
W	4/30	Rise of oxygen 3, symbiosis *Reading: TBA*	
Week 15		**Astrobiology**	
M	5/5	Origin of life *Readings: excerpts from Lane (2009) and Hazen (2005)*	
W	5/7	Astrobiology and life elsewhere? ****Proposal/review paper due (in class 5/7/2014)*** ****Final exam (take home exam) assigned at the end of class***	
Final exam period (Wednesday, 5/14, 10:30-12:30)			
W	**5/14**	****Final exam due (hard copy or electronically by e-mail) at the start of the final exam period***	