GEOL 165: Metals and life on Earth

Prof. Seth John; T/Th 11-12:30

All of life on Earth depends on metals such as iron, zinc, and chromium, which are crucial micronutrients for every living thing, from the microscopic algae which inhabit the ocean, to animals, to humans. Metals can also be toxic to life when their concentrations are too high, and many of the most notable public health disasters relate to metal contamination in the environment, such as elevated lead from the burning of gasoline to the poisoning of well water with arsenic, to the effects of chromium poisoning made famous in the movie Erin Brokovich.

This class will explore the role of metals in life. We will start with the origin of the universe and the creation of metals, explore the unique chemistry of metals which allows them to have so many important biological functions, and discuss numerous examples of the ways in which metals have affected human life and our environment. Topics of discussion will include the role of metals in the first cells on earth, "geoengineering" Earth’s climate by adding iron to the ocean in order to stimulate algae blooms, and public health disasters including the occurrence of lead in the Flint, Michigan water supply and chromium in California groundwaters.

How do metals support life in the oceans?

How does metal pollution affect human life?

What role did metals play on the early Earth?
GEOL 165: Metals and life on Earth
Syllabus for Fall 2019

Instructor: Prof. Seth John
Office ZHS 271, ph. x00696, email: sethjohn@usc.edu
Office hours: _day_, _time_ am; or by appointment

Teaching Assistants: First Last: ZHS NUM; email@usc.edu
First Last: ZHS NUM; email@usc.edu
First Last: ZHS NUM; email@usc.edu

TAs will announce their office hours during discussion section meetings.

Lectures: Day & Day, 0:30-0:50 am, in ROOM 101

Discussion sections: 2 hours per week, in ROOM, varying times

*Please don’t switch discussion times without approval of the TAs*

- The first discussion section will meet during the 2nd week of the semester, the week beginning MONTH 0th — DO NOT MISS THE FIRST DISCUSSION SECTION MEETING!

Readings: Readings for this class include both articles from the popular press (magazines, newspaper articles, web articles, etc.) as well as articles from the scientific literature. At the beginning of the semester you will be provided with a pdf including most of the readings for the semester. Additional readings may be assigned during the semester.

*The readings are not a substitute for attending lecture* and do not cover exactly the same material, though we will of course discuss aspects of the reading during lecture. A list of the assigned reading for each class is provided on the final page of this syllabus.
About this course

Catalogue Description: The role of metals in life, from the origin of life to modern environmental problems. Lecture - 3 hours/wk; discussion - 2 hours/wk.

More detail: Metals are integral to the chemistry of life. This course will explore the relationship between metals and life, starting at the beginning of the universe and working up to modern day environmental problems. The chemistry and reactivity of metals will be explored in order to understand what makes metal atoms so special. The history of metals in the universe, in the solid Earth, and in the oceans will be explored. Then we study the specific biological roles which metals play in life processes such as photosynthesis, respiration, and cellular replication, followed by a more specific focus on the role of metals in human health. These topics will be explored through several case studies, including the role of iron (Fe) in the oceans, the man-made contamination of the environment with lead (Pb), the contamination of drinking water with arsenic (As), and the contamination of the food chain with mercury (Hg).

There are several themes that we intend to develop in this class, and these will unite the material we cover. These include:

- exploring how the basic chemistry of metals determines their chemical reactivity, and how that chemical reactivity determines their role in life
- learning the language of science, by comparing scientific journal articles to magazine articles written for the general public, to newspaper reports of scientific issues
- an appreciation of data visualization, the ways in which scientists and writers turn quantitative data (numbers) into figures (pictures) in order to convey ideas.

Learning objectives: By the end of the class, you should have gained a greater appreciation for what makes metal atoms special, and how these atoms influence all life on earth. Metal biochemistry is just one small part of science, but by diving deeply into a few small aspects of this field, I hope that you will not just learn new subject matter, but that you will also learn how science is done. As you begin to understand the language scientists use to describe their work and their findings, I hope you will appreciate what professional scientists do all day, and what it is which makes science such a fun (and occasionally frustrating) endeavour.

This course is intended for students with little or no science background, but it will require scientific and numerate thinking. In the process of exploring metals and life, the class will meet the learning objectives of the USC General Education program related to the Life Sciences (Category GE-D), including:

- gain an appreciation for science’s influences and applications to society in the past, present and future;
- gain a better understanding of scientific methods; from constructing models of the natural and living world, to testing the validity of these models using empirical evidence;
- understanding how data are generated, presented and interpreted
- learning how scientific discovery spurs technology growth and impacts society

All of these learning objectives are woven into every lecture addressed in some way in every reading assignment and lecture.
Class logistics

1. Grading - Grades are based on the following point system:

<table>
<thead>
<tr>
<th>Component</th>
<th>Points</th>
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<tbody>
<tr>
<td>Midterm Exam 1:</td>
<td>200</td>
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<tr>
<td>Midterm Exam 2:</td>
<td>200</td>
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<tr>
<td>Final Exam:</td>
<td>200</td>
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<tr>
<td>Discussion sections:</td>
<td>250</td>
</tr>
<tr>
<td>In-class written responses:</td>
<td>150</td>
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<tr>
<td>Extra credit</td>
<td>50</td>
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Total possible: 1050 points

At the end of the semester, grades are assigned as follows: >950 = A+; 900-949 = A; 850-899 = B+; 800-849 = B; 750-799 = C+; 700-749 = C; 650-699 = D+; 600-649 = D; 0-599 = F. We will try to give an indication around the middle of the semester about where each student stands. If you are caught cheating on any portion of the class, whether exams, in-class responses, or other, you will be withdrawn from the class with a grade of F.

2. Lectures & readings – A schedule of lecture topics is below, along with selected readings. The readings complement but do not duplicate the lectures. Attend – and engage yourself in – the lectures. Taking notes and asking questions will put you in the best position to do well on the exams (and thus get the best grade you can).

3. Exams – The exams will be multiple-choice. As required for classes at USC, the final exam will be an integrative evaluation, drawing on your knowledge from the whole course. Make-up exams are generally not permitted except in extreme circumstances such as a medical emergency. If you have to miss an examination because of illness or a USC-sanctioned event (such as athletic competition), you must provide notice (email is OK) before the exam start time, and you must provide documentation (afterwards is fine).

4. Recitation sections – The discussion sections are an integral part of this course. A major goal of this course is to teach you how science is done ‘in real life’. In order to do that, you must understand what how a scientific manuscript is written, and how data is presented in a scientific manuscript. In order to participate in the discussion, you must read the assigned articles before coming to your discussion section and prepare your notes! You are expected to arrive at each discussion section with notes, including scientific terms (no fewer than 6) with which you were unfamiliar, a list of 3-5 general questions about the paper topics and a list of 3-5 questions about specific details of the study presented in the articles. A copy of these notes must be turned in to the TA at the end of discussion. Recitation sections account for a significant portion of your grade (25% of the total) and will be assessed based on your participation in the discussion as well as the notes turned in to the TA. Material from discussion sections will show up on the exams, even if it was not directly discussed in lecture.

5. In-class written assignments – You will have the opportunity to respond to class material by answering in-class questions by writing a few sentences or drawing diagrams on notecards. These short-answer essays provide students an opportunity to reflect on the material they are learning in class and in the readings, and provide me with feedback about students’ progress. There will be twelve (12) in-class assignments over the course of the semester, occurring at ‘random’ unannounced times. Responses will be graded as either acceptable (15 points) or unacceptable (0 points). Students can earn a maximum of 150 points by completing these assignments meaning that of the twelve in-class
assignments given over the course of the semester you only need to respond to ten of them in order to receive full credit. This means that you get two opportunities to miss an in-class assignment without losing points, however there will be no opportunities to make up these assignments if you are not in attendance at the time when they are announced, regardless of reason.

6. Extra credit – Towards the end of the semester, opportunities for extra credit will be announced. I will discuss the ground rules in more detail towards the end of the semester, but the basic idea is to give you an opportunity to interact with the class material in a unique and creative way which is tailored to your own personal skills and interests. Examples might include all sorts of interesting approaches, such as evaluating the screenwriting techniques used to present scientific data in the movie Erin Brokovich, completing a research paper on a topic of metals in human health, composing a song inspired by the important biological role of iron in the human body…or just about whatever else you can come up with, as long as it demonstrates engagement with the class material.

7. Blackboard – The TAs and I will try to keep your grade record updated on Blackboard. I will also try to keep PDF copies of lecture slides posted there. However, the PDFs of the lecture slides do not provide all of the information that will be covered in lectures, so do not try to use them as a substitute for attending lectures.

8. Missed a lecture? – I appreciate that you may have a sick day or an extra-curricular event that forces an absence. To catch up, keep up with the assigned readings and lecture slides posted on Blackboard. The policy for missed discussion sections is outlined on the separate discussion section syllabus that you will receive during the 1st meeting.

9. Grade Appeals – If you wish to appeal a grade on an exam or other assignment, you may do so in the first instance with your TA. If the issue is not resolved with your TA, you may approach Prof. John with the issue. If you appeal a grade, be aware that you may end up with a lower grade than you started with on a given question or assignment!
Other important information

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to Prof. John (or to your TA) as early in the semester as possible. If you approach us the day before an exam, it may be difficult to accommodate all of your needs! DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity
USC seeks to maintain an optimal learning environment. Academic honesty means respecting the intellectual property of others, with the expectation that individual work will be submitted unless otherwise allowed by an instructor. Students are obliged both to protect one’s own academic work from misuse by others as well as to avoid using another’s work as one’s own. All students are expected to understand and abide by these principles. Academic misconduct will not be tolerated in this class, and will be subject to disciplinary action.

SCampus, the Student Guidebook, contains the Student Conduct Code in Section 11, with recommended sanctions in Appendix A:
http://www.usc.edu/dept/publications/SCAMPUS/gov/
If there is any suspicion of academic dishonesty, students will be referred to the Office of Student Judicial Affairs and Community Standards for further review. The Review process is described at: http://www.usc.edu/student-affairs/SJACS/
Further information about USC’s guidelines for appropriate scientific conduct can be found here:
https://policy.usc.edu/scientific-misconduct/

Statement of University and Instructor Responsibilities and Liabilities
Field and laboratory activities have associated risks. We have worked to minimize these, but neither USC nor the instructors (Prof. John or the TAs) can assume liability. You will be required to sign a USC liability waiver for off-campus fieldtrips, as well as waiver forms for the specific sites where we will be guests. For the lab activities, you will be provided safety warnings and safety equipment, as appropriate. It is your responsibility to maintain safe practices.

Support Systems
USC provides several support services, the details for which can be found at:
https://undergrad.usc.edu/services/support-systems/
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<th>Lecture topic</th>
<th>Other events</th>
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<td>2</td>
<td>The periodic table and the elements of life</td>
<td>Labor day</td>
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<td>3</td>
<td>The special biological role of metals</td>
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<td>4</td>
<td>Iron I: Photosynthesis and respiration</td>
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<td>5</td>
<td>Iron II: The fight for iron between humans and our germs</td>
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<td>6</td>
<td>Iron III: Marine ecosystems</td>
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<td>7</td>
<td>Chromium: The ‘Erin Brokovich’ element</td>
<td>Midterm 1</td>
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<td>7</td>
<td>Arsenic I: The public health crisis, origins and solutions</td>
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<td>9</td>
<td>Arsenic II: Health effects of arsenic poisoning</td>
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<td>Mercury I: Environmental sources and movement of Hg</td>
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<td>11</td>
<td>Mercury II: Bioaccumulation and health effects of Hg</td>
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<td>12</td>
<td>Lead I: Lead in the environment and human body</td>
<td>Midterm 2</td>
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<td>13</td>
<td>Lead II: Health effects of lead</td>
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<td>14</td>
<td>Lead III: The Flint Michigan water crisis</td>
<td>Thanksgiving holiday</td>
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<td>15</td>
<td>Metals and the history of life on Earth</td>
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**FINAL**

Date: For the date and time of the final for this class, consult the USC Schedule of Classes at classes.usc.edu.
Readings

Week 1: History of the universe; history of life

Class reading
- Artemis Spyrou and Hendrik Schatz, 2018, Elements from the stars: The unexpected discovery that upended astrophysics 66 years ago, The Conversation.
- Warmflash, 2016, Did Life Come from Another World?, Scientific American

Discussion Group Reading
- None (discussion groups begin during Week 2)

Week 2: The periodic table and the elements of life

Class reading
- The Transmutation of Elements, Scientific American, 1926.
- Elements from the stars: The unexpected discovery that upended astrophysics 66 years ago.

Discussion Group Reading
- Vandenbroucke et al., Metal-induced malformations in early Palaeozoic plankton are harbingers of mass extinction, Nature Geoscience, 2015.

Week 3: The special biochemistry of metals

Class reading

Discussion Group Reading

Week 4: Iron I: Photosynthesis and respiration

Class reading
- Campbell, Photosynthesis, in Biology, 1996.

Discussion Group Reading

Week 5: Iron II: The fight for iron between humans and our germs

Class reading
• Gould, How fungi steal zinc from your body, Scientific American 2012.
• Finkel, Elizabeth, Malaria infection linked to iron in red blood cells, Cosmos Magazine, 2018.

Discussion Group Reading
• Pishchanny et al., Specificity for Human Hemoglobin Enhances Staphylococcus aureus Infection, Cell Host and Microbe, 2010.

Week 6: Iron and marine ecology
Class reading
• Buessler, Fertilizing the Ocean with Iron, WHOI, 1999.
• Powell, What Are the Possible Side Effects? The uncertainties and unintended consequences of manipulating ecosystems, Oceanus, 2008.
• Powell, Will Ocean Iron Fertilization Work? Getting carbon into the ocean is one thing, Keeping it there is another, Oceanus 2008.

Discussion Group Reading
• Martin et al., Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean, Nature 1994.

Week 7: Chromium: The ‘Erin Brokovich’ element
Class reading
• Agency for Toxic Substances and Disease Registry Case Studies in Environmental Medicine (CSEM) Chromium Toxicity, CSEM, 2000

Discussion Group Reading
• Bos, Carole, ERIN BROCKOVICH (ANDERSON v PG&E), 2005.
• Pearl, The Town Erin Brockovich Rescued Is Basically a Ghost Town Now, Vice, 2015.
• Izbicki, et al., Cr(VI) occurrence and geochemistry in water from public-supply wells in California, Applied Geochemistry 2008.

Week 8: Arsenic I - The public health crisis, origins and solutions
Class reading
• How the West poisoned Bangladesh; The Independent, 2016.
• Little, Arsenic Pills and Lead Foundation: The History of Toxic Makeup, National Geographic, 2016.

Discussion Group Reading
Week 9: Arsenic II - Health effects of arsenic poisoning

Class reading
- Is arsenic the worst chemical in the world?, Wired, 2012.

Discussion Group Reading
- Arsenic toxicity and potential mechanisms of action; Toxicology Letters, 2002.

Week 10: Mercury I – Environmental sources and movement of Hg

Class reading
- Schneider et al., 2019. Mercury pollution from decades past may have been re-released by Tasmania’s bushfires, The Conversation, 2019.

Discussion Group Reading
- Davidson, O.G. Even the Bottom of the Grand Canyon is Now Contaminated, National Geographic 2015.
- Walters et al., Mercury and selenium accumulation in the Colorado River food web, Grand Canyon, USA, Environmental Toxicology and Chemistry, 2015.

Week 11: Mercury II – Bioaccumulation and health effects of Hg

Class reading
- Barboza, Women, kids urged to avoid mercury-tainted fish from California lakes, LA Times, 2003.

Discussion Group Reading
- Oken et al., Maternal fish consumption, hair mercury, and infant cognition in a US cohort.

Week 12: Lead I - The history of environmental Pb contamination

Class reading
- Lead: America’s Real Criminal Element; Mother Jones, 2016.
- Tong et al. Environmental lead exposure: a public health problem of global dimensions.
- The clean room, Cosmos, 2014.

Discussion Group Reading
• Ericson et al., Skeletal Concentrations of Lead in Ancient Peruvians, NEJM, 1979.

Week 13: Lead II - The health effects of Pb

Class reading
• Shalat, 2016. Toxic lead can stay in the body for years after exposure, The Conversation.
• Sjeda and Meynard, 2017. Is lead in the US food supply decreasing our IQ?
• Lead in food: A hidden health threat, EDF, 2017.

Discussion Group Reading
• Delile et al., Lead in ancient Rome’s city waters, PNAS 2014.

Week 14: Lead III - The Flint Michigan water crisis

Class reading
• Clark, 2018, Nothing to worry about, the water is fine, The Guardian, 2018.

Discussion Group Reading
• Renwick, Dustin, Five years on, the Flint water crisis is nowhere near over, National Geographic, 2019.

Week 15: Metals and the history of oxygen on Earth

Class reading
• Rayner-Canham and Grandy, Molybdenum and evolution, Education in Chemistry, 2011.
• Low oxygen and molybdenum in ancient oceans delayed evolution of life by 2 billion years, UCR, 2009.

Discussion Group Reading
• Enriquez and Do, Bioavailability of Metal Ions and Evolutionary Adaptation, Life, 2012.