Chemistry 460/560 – Prebiotic Chemistry
Portland State University, Spring 2014

General Information
Class meetings (required): Monday and Wednesday evenings; 4:40 – 6:30 pm, Cramer 324
Dr. Lehman’s Office Hours: Wed 2:30 – 4:30 pm; and by appt.
Best way to contact Dr. Lehman: by email! (niles@pdx.edu)

Prerequisites
The prerequisite for enrollment in CH 460/560 is completion of, or concurrent enrollment in, CH 492
(or equivalent), or my consent. Essentially you must have had a full year of majors’ level biochemistry.
CH 350 is usually not sufficient. I will also expect passage of a full year of organic chemistry.

Course Overview
Chem 460/560 is an introduction to prebiotic chemistry that has been approved to satisfy partially the
Chemistry Ph.D. core course requirement at Portland State University. It also partially satisfies a 400-
level elective requirement for undergraduates majoring in Chemistry or Biochemistry. We will meet
two afternoons per week during the term. In the first 7 weeks I will provide an overview on the current
theories of the chemical origins of life on the Earth some 4 billion years ago. For the last 3 weeks we
will read papers in the primary literature and discuss them via students’ oral presentations to the class.

Grading
There will be 100 points possible in the course, and grades will be assigned on a straight scale: (>85%
= A range; >75% = B range; >65% = C range; <65 % = F). Plus and minus grades will only be given
for students whose total points fall near a grade boundary but clearly outside the statistical “bubble” of
the other students (i.e., for outliers). Grades will be assigned for student presentations (30%), the
 midterm examination (30%), and the final exam (40%). Each student will be the primary presenter for
some literature readings we will have after the first six of weeks of class. Basically each student must
pick a prebiotic chemist from the list of 20 that I provide below, and “become” that person for the
duration of the course. We will start choosing in week #2, so please begin to look up some of the
works of these scientists to be able to choose according to your own interests, or I will assign them to
you. The 30 points of the student presentation grade will have two components. First, 20 points will be
available from the presentations that you do in class during the final three weeks using PowerPoint or
Keynote. You will have to present at least two slides on the biography of the person, and then the
remaining slides (to fill a 30-minute time slot) presenting the data and conclusions from 1–3 papers
that scientist has published in the field. You will also need to hand in a 1-page written summary of
your presentation to me on the date it is given orally in class. You will be graded on oral clarity,
coverage and understanding of the papers, and on the clarity of your written summary. I – and the
graduate students in the class – will go first, so the undergrads will at least have one lecture to see
“how it is done.” (To receive CH560 graduate credit, in addition to going first, graduate students will
have to: i) be available to undergrads to help them prepare and practice their presentations, ii) critique
each undergrad presentation along with me, and iii) write a 5-page summary of their own oral
presentations.) Second, the remaining 10 points are available for in-class participation. At any time
during the class I may call on a “scientist” and ask him or her to explain one of their experiments or
how their work influences the topic at hand. I will not expect a perfect answer, but I will give points as
follows: student consistently responds in a manner displaying knowledge and integration of their “scientist’s” work = 10 pts; student is usually good at this but makes some errors = 7 pts.; student displays some knowledge of their “scientist” but is generally unprepared to explain it in any detail = 3 pts; student not present or unresponsive when questioned about their “scientist” = 0 pts.

Course Policies
I will expect all students to conduct themselves responsibly during class periods and observe academic honesty during exams. Students may assist each other with the in-class presentations but must work entirely independently on the exams. All cell phones are to be turned off during class!

Lecture Schedule (handouts and extra readings will be available on the course D2L website)

<table>
<thead>
<tr>
<th>Date</th>
<th>Reading</th>
<th>Presenter(s)</th>
<th>Topics</th>
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<tbody>
<tr>
<td>Mon, March 31</td>
<td>P&amp;G, Ch. 1</td>
<td>NL</td>
<td>overview of prebiotic chemistry</td>
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<tr>
<td>Wed, April 2</td>
<td>P&amp;G, Ch. 2</td>
<td>NL</td>
<td>habitable zones</td>
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<tr>
<td>Mon, Apr 7</td>
<td>P&amp;G, Ch. 3</td>
<td>NL</td>
<td>life / atoms / water / atmospheres</td>
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<td>Wed, Apr 9</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>Oparin / Haldane theories</td>
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<td>Mon, Apr 14</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>amino acids</td>
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<td>Wed, Apr 16</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>sugars – the formose reaction</td>
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<td>Mon, Apr 21</td>
<td>Burton et al. (2012)</td>
<td>NL</td>
<td>meteorites</td>
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<tr>
<td>Wed, Apr 23</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>nt synthesis – Oró &amp; Sutherland</td>
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<tr>
<td>Mon, Apr 28</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>RNA synthesis, part 1</td>
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<tr>
<td>Wed, Apr 30</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>RNA synthesis, part 2</td>
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<td>Mon, May 5</td>
<td>P&amp;G, Ch. 4</td>
<td>NL</td>
<td>the roots of metabolism</td>
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<td>Wed, May 7</td>
<td>P&amp;G, Ch. 5; Cody 2007 (HO)</td>
<td>NL</td>
<td>in vitro evolution experiments</td>
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<tr>
<td>Mon, May 12</td>
<td>P&amp;G, Ch. 6</td>
<td>NL</td>
<td>lipids &amp; protocells</td>
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<tr>
<td>Wed, May 14</td>
<td>Joyce 2007 (pdf &amp; HO)</td>
<td>NL</td>
<td></td>
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<td>Mon, May 19</td>
<td>papers TBD</td>
<td>grad students: Dr. Lehman, Tharuka, Fenil</td>
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<tr>
<td>Wed, May 21</td>
<td>papers TBD</td>
<td>grad students: Chun, Patrick</td>
<td></td>
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<tr>
<td>Mon, May 26</td>
<td>no class – Memorial Day</td>
<td>papers TBD</td>
<td>u/g students: TBA: Matthew, Jarrod, xxx</td>
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<td>Wed, May 28</td>
<td>papers TBD</td>
<td>u/g students: TBA: Brian, Derek, xxx</td>
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<tr>
<td>Mon, June 3</td>
<td>no class – instructor out of town</td>
<td>papers TBD</td>
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<tr>
<td>Wed, June 5</td>
<td>papers TBD</td>
<td>u/g students: TBA: Brian, Derek, xxx</td>
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Mon, June 9  3:30 – 5:30 pm Final exam – P&G Chapters 1–6, all handouts, & student presentations
Textbook
We will be using the book *Astrobiology, A Brief Introduction* (2nd Edition, 2011), by Kevin Plaxco & Michael Gross. This is a required textbook, and we will cover Chapters 1–6, although there is some interesting material in the later chapters that you can read on your own. To get a head start on the class, buy the book and read chapter 1 before the first lecture. You will be tested on this material during week #4. Other readings will be provided later, including Chapter 8 in the textbook, “*Planets and Life: The Emerging Science of Astrobiology*” (Cambridge University Press, 2007). This textbook is an edited compilation by Woody Sullivan and John Baross of papers related to the origins of life. Chapter 8 is written by George Cody and James Scott and is entitled, “The roots of metabolism.”

The Ten Reactions that Define the Field

1. \( \text{CH}_4 + \text{H}_2 + \text{H}_2\text{O} + \text{NH}_3 \rightarrow \text{HCN} + \text{HCOOH} \rightarrow \text{glycine} \) (Miller, 1953)
2. \( \text{HCHO} + \text{CHOCH}_2\text{OH} \rightarrow \text{ribose} \) (Breslow, 1959)
3. \( 5\text{HCN} + \text{UV light} \rightarrow \text{adenine} \) (Oró, 1961)
4. \( \text{ribose}-5\text{P} + \text{NH}_3 + \text{NH}_2\text{CN} + \text{HC≡C—CN} \rightarrow \text{cytidine} \) (Orgel, 1971)
5. \( \text{A} + \text{B} + \text{AB} \leftrightarrow \text{A•B•AB} \rightarrow \text{AB•AB} \leftrightarrow 2\text{AB} \) (von Kiedrowski, 1986)
6. \( \text{FeS} + \text{H}_2\text{S} \rightarrow \text{CH}_3—\text{CH}_3, \text{CH}_2—\text{CH}_2 \) (Wächtershäuser, 1990)
7. \( \text{R}_1—\text{S~CO}—\text{R}_2 + \text{X—OH} + \text{Y—OH} \rightarrow \text{X—Y} + \text{H}_2\text{O} \) (deDuve, 1991)
8. \( n\text{ImATP} + \text{clay} \rightarrow (\text{AMP})_n \) (Ferris, 1996)
9. \( \text{RNA} + (\text{NTP})_n \rightarrow 2\text{RNA} \) (Bartel, 2001)
10. \( \text{NH}_2\text{CN} + \text{CHOCH}_2\text{OH} + \text{HC≡C—CN} + \text{P}_i \rightarrow \text{cytosine MP} \) (Sutherland, 2009)

Twenty Prebiotic Chemists of note:

- Stanley Miller
- Joan Oró
- Leslie Orgel
- Jerry Joyce
- Jack Szostak
- Arthur Weber
- Sherwood Chang
- John Sutherland
- Donna Blackmond
- Jim Ferris
- Steve Benner
- Dave Deamer
- Christian DeDuve
- Günter Wächtershäuser
- Günter von Kiedrowski
- Manfred Eigen
- Sandra Pizzarello
- Albert Eschenmoser
- Ram Krishnamurthy
- Dave Bartel
Prebiotic Synthesis of Small Molecules


**The Encapsulation Problem**


**Metabolism-first Experiments**


Self-replicating and Autocatalytic Chemical Systems


**Polymers and Ribozymes**


**The Chirality Problem**


**Crystals and Other Possible Life Forms**


**Extraterrestrial Origins**


**The Definition of Life and Philosophical Issues of Abiogenesis**
