BioEE 668 – Principles of Biogeochemistry

Spring, 2006; 4 credits

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Office Hours: By appointment.

Scheduled Class Hours: Tuesdays & Thursdays, 10:10 -12:05

Grading: Letter grades or S/U

Text: Schlesinger, W. H. 1997. Biogeochemistry: An Analysis of Global Change. 2nd Edition, Academic Press, San Diego.

Workload:

Regular assigned readings (from text and from literature).
Active participation in discussion and attendance at lectures. (10%)
Leadership of one discussion. (10%)
Take-home problem sets (3). (3 x 5%)
Take-home exams (2). (2 x 15%)
Term paper and oral presentation. (35%)

Grades will be determined from performance in the above activities (% of grade). Take-home exams will require integration of material from lectures, readings, and Friday afternoon biogeochemistry seminars (attendance at these seminars is strongly encouraged).

Definition of biogeochemistry: the science dealing with "biotic controls on chemistry of the environment [and] with the geochemical control of the structure and function of ecosystems" (Howarth, R. W. 1984. *Biogeochemistry*, 1: preface).

Some appropriate journals and sources: *Biogeochemistry, Global Biogeochemical Cycles, Nature, Limnology & Oceanography, Ecosystems, Ambio, BioScience,* SCOPE books (Wiley & Sons, Kluwer, Island Press)

BioEE 668 Principles of Biogeochemistry

Syllabus, Spring 2006

R. W. Howarth & C. L. Goodale

Date	Topic	Assignment Due
Jan. 24	Introduction and some review of some chemistry (RWH)	
Jan. 26	Continued review, and intro. to thermodynamics (RWH)	
Jan. 31	Energetics and oxidation-reduction chemistry (RWH)	Prob. Set #1
Feb. 2	Continuation of e- acceptors and donors (RWH)	Prob. Set #2
Feb. 7	Global history and biogeochemistry (CLG)	Prob. Set #3
Feb. 9	Basic C cycle: NPP & decomposition (CLG)	
Feb. 14	Sediment decomposition & modeling (RWH)	
Feb. 16	Basic N cycle – processes and overview (RWH) **	*Discussion*
Feb. 21	Geology, weathering, and soil development (CLG)	
Feb. 23	Biogeochemical cycling on land: inputs & cycles (CLG)	
Feb. 28	Terrestrial nutrient limitation (CLG)**	*Discussion*
Mar. 2	Essential & limiting elements, and stoichiometry (RWH)	
Mar.7	Aquatic nutrient limitation: definitions and evidence (RWH) **	*Discussion*
Mar. 9	Aquatic nutrient limitation: driving mechanisms (RWH) **	*Discussion*, Paper Topics,
Mar. 14	N fixation in aquatic ecosystems (RWH) **	*Discussion*
Mar. 16	Review of student project topics (CLG)	Exam #1
Mar. 21 & 23	SPRING BREAK	
Mar. 28	Watershed biogeochemistry (CLG) **	*Discussion*
Mar. 30	Acid rain: terrestrial ecosystems (CLG)	
Apr. 4	Acid rain: aquatic ecosystems (RWH) **	*Discussion*
Apr. 6	N deposition: effects on terrestrial ecosystems (CLG) **	*Discussion*
Apr. 11	Human alteration of the N cycle at global and regional scales (RWH)	
Apr. 13	Diversity and biogeochemical function (Osvaldo Sala)	
Apr. 18	Human alteration of the global C cycle: sources & sinks (CLG)	
Apr. 20	Human alteration of the global C cycle: mechanisms (CLG) **	*Discussion*
Apr. 25	Climate change and biogeochemical cycles (CLG) **	*Discussion*
Apr. 27	New frontiers in biogeochemistry (CLG)	Exam #2
May 2	Student presentations	
May 4	Student presentations	

*** Student-led paper discussions*

Expanded Syllabus, Spring 2006

Date Topic Assignment Due

1) Jan. 24 Introduction and some review of some chemistry (RWH)
- Schlesinger, Chp. 1: Intro. (p. 3-13);
- Gorham, E. 1991. Biogeochemistry: its origins and development. *Biogeochemistry* 13:199-239.

2) Jan. 26 Continued review and intro. to thermodynamics (RWH)
- Libes, S. 1992. The importance of oxygen. P. 107-128, in S. Libes, ed. *An Introduction of Marine Biogeochemistry.* Wiley & Sons.

3) Jan. 31 Energetics and oxidation-reduction chemistry (RWH) Prob. Set #1
- Schlesinger, Chp. 7: Freshwater - Redox (p. 226-242); Chp. 8: Estuaries (p. 279-286).
- Howarth, RW. 1993. Microbial processes in salt-marsh sediments. P. 239-259. in TE Ford, Ed. *Aquatic Microbiology: An Ecological Approach.* Blackwell, Boston.

4) Feb. 2 Continuation of e- acceptors and donors (RWH) Prob. Set #2
- Howarth, RW. 1984. The ecological significance of sulfur in the energy dynamics of salt-marsh and coastal marine sediments. *Biogeochemistry* 1:5-27
- Lein, AY & MV Ivanov. 1982. Interactions of C, S, and O cycles in continental and marginal seas. In Howart et al. eds, *Sulfur Cycling on the Continents.* Wiley & Sons.

5) Feb. 7 Global history and biogeochemistry (CLG) Prob. Set #3
- Schlesinger, Chp. 2: Origins (p. 14-45)
- Nisbet, EG & NH Sleep. 2001. The habit and nature of early life. *Nature* 409:1083-1091.

6) Feb. 9 Basic C cycle: NPP & decomposition (CLG)
- Schlesinger Chp. 5: The Biosphere: Carbon Cycle (p. 127-165)

7) Feb. 14 Sediment decomposition & modeling (RWH)
- Schlesinger Chp. 9 Oceans p. 307-312
- Aller, R. C. 1982. The effects of macrobenthos on chemical properties of marine sediment and overlying water. Pages 53-102 In McCall, P. L., and M. J. S. Tevesz. Animal-Sediment Relations: The Biogenic Alteration of Sediments. Plenum.

8) Feb. 16 Basic N cycle – processes and overview (RWH) ** *Discussion*
- Bashkin & Howarth 2002a, Biogeochemical Cycles of N, p. 110-121 in *Modern Biogeochemistry*. Kluwer.
- An, S.M. and W.S. Gardner. 2002. Dissimilatory nitrate reduction to ammonium (DNRA) as a nitrogen link, vs. denitrification as a sink in a shallow estuary (Laguna Madre/Baffin Bay, Texas). *Mar. Ecol. Prog. Ser.* 237- 41-50.

9) Feb. 21 Geology, weathering, and soil development (CLG)
- Schlesinger Chp. 4: Lithosphere (p. 88-126)
- Vitousek, PM, OA Chadwick, TE Crews, JH Fownes, DM Hendricks, D Herbert.. 1997. Soil and ecosystem development across the Hawaiian islands. *GSA Today* 7(9):1-7.

10) Feb. 23 Biogeochemical cycling on land: inputs, cycles, losses (CLG)
- Schlesinger Chp. 6: The Biosphere: Biogeochemical cycles (p. 166-223)

11) Feb. 28 Terrestrial nutrient limitation (CLG)** ***Discussion***

- Chapin, FS, PM Vitousek & K Van Cleve. 1986. The nature of nutrient limitation in plant communities. *American Naturalist* 127:48-58.
- Optional: Korner, Ch. 2003. Limitation and stress – always or never? *J. Veg. Sci.* 14:141-143.

12) Mar. 2 Essential & limiting elements, and stoichiometry (RWH)

- Bashkin & Howarth 2002b, Biogeochemical Cycles of Trace Elements, p. 161-196 in *Modern Biogeochemistry*. Kluwer.

13) Mar. 7 Aquatic nutrient limitation: definitions and evidence (RWH) ** ***Discussion***

- Howarth, R. W., and R. Marino. 2006. Nitrogen as the limiting nutrient for eutrophication in coastal marine ecosystems: Evolving views over 3 decades. *Limnol. Oceanogr.*, 51:364-376.
- Hecky, RE & P Kilham. 1988. Nutrient limitation of phytoplankton in fresh water and marine environments: a review of recent evidence on the effects of enrichment. *Limnology & Oceanography* 33:796-822.

14) Mar. 9 Aquatic nutrient limitation: driving mechanisms (RWH) ** ***Discussion*, Paper Topics,**

- Blomqvist, S, A Gunnars, and R Elmgren. 2004. Why the limiting nutrient differs between temperate coastal seas and freshwater lakes: A matter of salt. *Limnol. Oceanogr.* 49:2236-2241.

15) Mar. 14 N fixation in aquatic ecosystems (RWH) ** ***Discussion***

- Marino, R, et al. 2002. Ecological and biogeochemical interactions constrain planktonic nitrogen fixation in estuaries. *Ecosystems* 5: 719-725.
- Vitousek, PM et al. 2002. Towards an ecological understanding of biological nitrogen fixation. *Biogeochemistry* 57:1-45.

16) Mar. 16 Review of student project topics (CLG) ***Discussion*, Exam #1**

- Cleveland, CC et al. 1999. Global patterns of terrestrial biological nitrogen (N_2) fixation in natural ecosystems. *Global Biogeochemical Cycles* 13(2):623-645.

Mar. 21 & 23 SPRING BREAK

17) Mar. 28 Watershed biogeochemistry (CLG) ** ***Discussion***

- Church, MR. 1997. Hydrochemistry of forested catchments. *Ann. Rev. Earth & Planetary Sci.* 25:23-59.
- Likens, GE, FH Bormann, RS Pierce, and WA Reiners. 1978. Recovery of a deforested ecosystem. *Science* 199(4328):492-496.
- *Optional*: Fisher, SG, RA Sponseller, and JB Heffernan. 2004. Horizons in stream biogeochemistry: flowpaths to progress. *Ecology* 85(9):2369-2379.

18) Mar. 30 Acid rain: terrestrial ecosystems (CLG)

- Driscoll et al. 2001. Acidic deposition in the northeastern United States. *BioScience* 51:180-198.
- Sharpe. 2002. Acid deposition explains sugar maple decline in the east. *BioScience* 52(1):4-6.
- *Optional:* Van Breemen, N & RF Wright. 2004. History and prospect of catchment biogeochemistry: a European perspective based on acid rain. *Ecology* 85(9):2363-2368.

19) Apr. 4 Acid rain: aquatic ecosystems (RWH) ** ***Discussion***

- Cook, RB & CA Kelley. 1992. Sulphur cycling and fluxes in temperate dimictic lakes. p. 145-188 in RW Howarth et al., eds. *Sulphur Cycling on the Continents.* Wiley & Sons.

- Dillon, P.J. and H.E. Evans. 2001. Long-term changes in the chemistry of a soft-water lake under changing acidic deposition rates and climate fluctuations. *Verh. Internat. Verein. Limnol.* 27: 2615-2619.

20) Apr. 6 N deposition: effects on terrestrial ecosystems (CLG) ** ***Discussion***

- Aber et al. 1998. Nitrogen saturation in temperate forest ecosystems: hypotheses revisited. *BioScience* 48(11):921-934.
- Magill, AH et al. 2004. Ecosystem response to 15 years of chronic nitrogen additions at the Harvard Forest LTER, Massachusetts, USA. *Forest Ecology & Management* 196:7-28.

21) Apr. 11 Human alteration of the N cycle at global and regional scales (RWH)

- Howarth, RW et al. 2002a. Nitrogen use in the United States from 1961-2000 and potential future trends. *Ambio* 31:88-96.
- Howarth, RW, A Sharpley, and D Walker. 2002b. Sources of nutrient pollution to coastal waters in the United States: implications for achieving coastal water quality goals. *Estuaries* 25: 656-676.

22) Apr. 13 Diversity and biogeochemical function (Osvaldo Sala)

- To be determined

23) Apr. 18 Human alteration of the global C cycle: sources & sinks (CLG)

- Schlesinger Chp. 11: The global C cycle (p. 358-381)
- Schimel DS et al. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. *Nature* 414:169-172.

24) Apr. 20 Human alteration of the global C cycle: mechanisms (CLG) ** ***Discussion***

- Nadelhoffer et al. 1999. Nitrogen deposition makes a minor contribution to carbon sequestration in temperate forests. *Nature* 398:145-148.
- Körner, Ch. et al. 2005. Carbon flux and growth in mature deciduous forest trees exposed to elevated CO2. *Science* 309:1360-1363.

25) Apr. 25 Climate change and biogeochemical cycles (CLG)

- Rustad, LE, et al. 2001. A meta-analysis of the response of soil respiration, net nitrogen mineralization and aboveground plant growth to experimental ecosystem warming. *Oecologia* 126(4): 543-562.

26) Apr. 27 New frontiers in biogeochemistry (CLG) **Exam #2**

- Likens, GE. 2004. Biogeochemistry: some opportunities and challenges for the future. *Water Air & Soil Pollution: Focus* 4:5-24.
- Schlesinger, WH. Better living through biogeochemistry. *Ecology* 85(9): 2402-2407.

27) May 2 Student presentations

28) May 4 Student presentations

** Student-led paper discussions