

Principles of Stable Isotopes
CSS 523—(Winter 3 credits)
TR 10:00-11:20 am, ALS 3006

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Course goal: An introduction to the principles and applications of stable isotopes with special reference to ecological processes.

Learning objectives:

- Explain the difference among isotopes of a given element and describe how this affects their behavior in nature
- Describe how temperature affects isotopic fractionation
- Know what the international standard is for each of the light isotopes, and why things are compared to a standard
- Know what a working standard is, why each lab has them, and identify characteristics that make a material a good working standard
- Relate how isotopic fractionation can tell you about material sources and substance purity
- Describe how isotopes have been used to infer past climate and past vegetation patterns
- Describe the difference between natural abundance and tracer studies; explain why ^{15}N is primarily used as a tracer
- State how ^{18}O can be used as a tracer, even at natural abundance levels
- Describe how several of the light isotopes have been used to further understanding of ecological and environmental problems, including nutrient cycling, carbon storage, dietary analysis, and substance purity and origin
- Describe how advances in technology have gone hand-in-hand with advances in scientific understanding

Grading:	Homework assignments (4 @ 10 points each)	40%
	Special topic presentation	20%
	Class participation	10%
	Final exam (oral)	30%

Study materials: Article and PowerPoint PDFs as distributed

CSS 523—Lecture Schedule

Week	Date	Topic	Recommended reading*
1	T, 5 Jan	Introduction	
	R, 7 Jan	Isotopic principles and discussion of the Kendall and Caldwell chapter	Kendall, C., and E.A. Caldwell. 1998. Fundamentals of isotope geochemistry. p. 51-86. <i>In</i> C. Kendall and J. J. McDonnell, eds. <i>Isotope Tracers in Catchment Hydrology</i> . Elsevier Science B.V. [p. 51-64, 70-77 in particular]
2	T, 12 Jan	Isotopic principles continued...	Sulzman. 2007. Stable isotope chemistry and measurement: a primer. p. 1-21. <i>In</i> R. Michener and K. Lajtha, eds. <i>Stable Isotopes in Ecology and Environmental Science</i> . Blackwell Publishing, Malden, MA.
	R, 14 Jan	Mass spectrometer—basics of instrumentation and lab tour	Barrie, A., and S.J. Prosser. 1996. Automated analysis of light-element stable isotopes by isotope ratio mass spectrometry. p. 1-46. <i>In</i> T. W. Boutton and S. Yamasaki, eds. <i>Mass Spectrometry of Soils</i> . Marcel Dekker, Inc., New York.
3	T, 19 Jan	Guest Lecture on laser instruments for isotope measurement, Dr. Manish Gupta	
	R, 21 Jan	Isotopes and QA/QC: working with data	Jardine, T.D. and R.A. Cunjak. 2005. Analytical error in stable isotope ecology. <i>Oecologia</i> . 144:528-533.
4	T, 26 Jan	Classic example of fractionation: ^{13}C during photosynthesis	O'Leary, M.H. 1988. Carbon isotopes in photosynthesis. <i>BioScience</i> 38:328-336.
	R, 28 Jan	Water cycle basics: ^2H and ^{18}O	TBD
5	T, 2 Feb	Three examples of mixing	Balesdent, J., and A. Mariotti. 1987. Natural ^{13}C abundance as a tracer for studies of soil organic matter dynamics. <i>Soil Biol. Biochem.</i> 17:25-30; Flanagan, L.B., and J.R. Ehleringer. 1998. Ecosystem-atmosphere CO_2 exchange: interpreting signals of change using stable isotope ratios. <i>Trends Ecol. Evol.</i> 13:10-14; TBD
	R, 4 Feb	Mathematics—mixing models	Phillips, D.L., Gregg, J.W., 2001. Uncertainty in source partitioning using stable isotopes. <i>Oecologia</i> 127:171-179; Phillips, D.L., Gregg, J.W., 2003. Source partitioning using stable isotopes: coping with too many sources. <i>Oecologia</i> 136:261-269.

Week	Date	Topic	Recommended reading*
6	T, 9 Feb	¹⁵ N–tracer basics	Hart, S.C., and D.D. Myrold. 1996. ¹⁵ N tracer studies of soil nitrogen transformations. p. 225-245. In T. W. Boutton and S. Yamasaki, eds. <i>Mass Spectrometry of Soils</i> . Marcel Dekker, Inc., New York.
	R, 11 Feb	Isotope dilution demonstration	
7	T, 16 Feb	¹⁵ N–gross rate studies	Murphy, D.V., S. Recous, E.A. Stockdale, I.R.P. Fillery, I.R.P., L.S. Jensen, D.J. Hatch, and K.W.T. Goulding. 2003. Gross nitrogen fluxes in soil: Theory, measurement and application of N-15 pool dilution techniques. <i>Adv. Agron.</i> 79:69-118.
	R, 18 Feb	Mathematics–isotope dilution	
8	T, 23 Feb	Guest lecture on isotopes in hydrology by Dr. Jeff McDonnell	
	R, 25 Feb	Student Presentations	
9	T, 2 Mar	Stable isotope probing (SIP)	Dumont, M.G., and J.C. Murrell. 2005. Stable isotope probing - linking microbial identity to function. <i>Nature Reviews Microbiology</i> 3:499-504. Butler, J.L., M.A. Williams, P.J. Bottomley, and D.D. Myrold. 2003. Microbial community dynamics associated with rhizosphere carbon flow. <i>Appl. Environ. Microbiol.</i> 69:6793-6800; Buckley, D.H., V. Huangyutitham, S.F. Hsu, and T.A. Nelson. 2007. Stable isotope probing with N-15(2) reveals novel noncultivated diazotrophs in soil. <i>Applied and Environmental Microbiology</i> 73:3196-3204.
	R, 4 Mar	Student Presentations	
10	T, 9 Mar	Secondary ion mass spectrometry (SIMS)	Cliff, J.B., P.J. Bottomley, D.J. Gaspar, and D.D. Myrold. 2002. Exploration of inorganic C and N assimilation by soil microbes with time of flight secondary ion mass spectrometry. <i>Appl. Environ. Microbiol.</i> 68:4067-4073.
	R, 11 Mar	Student Presentations	

Homework schedule (subject to modification):

Assignment	Topic	Due date
Homework #1	Basic isotope calculations	26 Jan
Homework #2	Mixing model calculations	9 Feb
Homework #3	Fractionation calculations	23 Feb
Homework #4	Isotope dilution calculations	9 Mar

Student presentations

Choose a topic of interest to you (some examples are given). Start with a literature search, but if you are having trouble getting anywhere, don't hesitate to ask for help. Your presentations should be about 25 min long and will be followed by up to 15 min of discussion.

- Isotopomer analysis (e.g., $^{14}\text{N}^{15}\text{NO}$ vs. $^{15}\text{N}^{14}\text{NO}$)
- $\Delta^{14}\text{C}$ analysis (e.g., taking advantage of “bomb” C for C turnover studies in plants and soils)
- ^{13}C -NMR (e.g., insights into soil organic matter composition and decomposition processes)
- ^{34}S applications
- ^{54}Fe applications (or ^{57}Fe)
- Stable isotopes in food purity/adulteration studies
- Stable isotopes as tools for archeology
- Use of stable isotopes to solve crimes
- Use of tunable laser diodes and isotopes to study ecosystem processes
- Stable isotopes in paleoclimate analyses

Final Exam:

- To be scheduled during finals week: several times most days will be available.

CSS 523—Literature ResourcesStable Isotopes—General references that are really useful

- Boutton, T.W., and S. Yamasaki. 1996. *Mass spectrometry of soils*. Marcel Dekker, Inc., New York, NY.
- Coleman, D.C., and B. Fry. 1991. *Carbon isotope techniques*. Academic Press, Inc., San Diego, CA.
- Dawson, T.E., and R.T.W. Siegwolf. 2007. *Stable isotopes as indicators of ecological change*. Academic Press, San Diego, CA.
- Ehleringer, J.R., A.E. Hall, and G.D. Farquhar. 1993. *Stable isotopes and plant carbon/water relations*. Academic Press, San Diego, CA.
- Fry, B. 2006. *Stable isotope ecology*. Springer, New York, NY.
- Griffiths, H. 1998. *Stable isotopes: integration of biological, ecological, and geochemical processes*. BIOS Scientific Publishers, Ltd., Oxford, UK.
- Hoefs, J. 1997. *Stable isotope geochemistry, 4th*. Springer-Verlag, Berlin, Germany.
- Kendall, C., and J.J. McDonnell. 1998. *Isotope tracers in catchment hydrology*. Elsevier, Amsterdam, The Netherlands.
- Knowles, R., and T.H. Blackburn. 1993. *Nitrogen isotope techniques*. Academic Press, Inc., San Diego, CA.

- Leng, M.J. 2006. *Isotopes in Palaeoenvironmental Research*. Developments in Paleoenvironmental Research, Vol. 10. Springer. Dordrecht, The Netherlands.
- Michener, R., and K. Lajtha. 2007. *Stable isotopes in ecology and environmental science*, 2nd edition. Blackwell Publishing, Malden, MA.
- Peterson, B.J., and B. Fry. 1987. Stable isotopes in ecosystem studies. *Annu. Rev. Ecol. Syst.* 18:293-320.
- Rundel, P.W., J.R. Ehleringer, and K.A. Nagy. 1989. *Stable isotopes in ecological research*. Ecological Studies 68. Springer-Verlag, New York, NY.
- Schimel, D.S. 1993. *Theory and application of tracers*. Academic Press, San Diego, CA.
- Stable Isotopes—Classic References
- Craig, H. 1952. The geochemistry of the stable carbon isotopes. *Geochem. Cosmochim. Acta* 3:53-92.
- Craig, H. 1961. Isotopic variations in meteoric waters. *Science* 133:1702-1703.
- Dansgaard, W. 1964. Stable isotopes in precipitation. *Tellus* 16:436-468.
- Hauck, R.D., S.W. Melsted, and P.E. Yankwich. 1958. Use of N-isotope distribution in nitrogen gas in the study of denitrification. *Soil Sci.* 86:287-291.
- Keeling, C.D. 1961. The concentrations and isotopic abundances of carbon dioxide in rural and marine air. *Geochim. Cosmochim. Acta* 24:277-298.
- Kirkham, D., and W.V. Bartholomew. 1954. Equations for following nutrient transformations in soil, utilizing tracer data. *Soil Sci. Soc. Am. Proc.* 18:33-34.
- Kirkham, D., and W.V. Bartholomew. 1955. Equations for following nutrient transformations in soil, utilizing tracer data. II. *Soil Sci. Soc. Am. Proc.* 19:189-192.
- Meselson, M. and F.W. Stahl. 1958. The replication of DNA in *Escherichia coli*. *Proc. Nat. Acad. Sci. USA* 44:671-682.
- Park, R., and S. Epstein. 1961. Metabolic fractionation of ¹³C and ¹²C in plants. *Plant Physiol.* 36:380-384.
- Urey, H.C. 1947. The thermodynamic properties of isotopic substances. *J. Chem. Soc.* :562-581.