Stable Isotopes in Ecosystems, Examination 1
October 10, 2006

Name ______key____________________
Student ID ___________________________

Please restrict your response to the space available; do not extend your answers to the back of the paper. Answer directly and fully - don't beat around the bush. The point values for each question are given in parentheses. Any notes you added to printouts of Winston Weatherly's notebook are allowed in answering the exam. All page references refer to Winston's notebook.

For this exam, **<u>you will have to choose</u>** from among the following data sets upon which you want to be examined: (a) page 481 and page 487 or (b) page 481 and page 499. Only one set (a or b) will be graded. Answer accordingly.

<u>Page 481</u>

Two years ago I spent the Labor Day holidays exploring some of the remote regions up and down the central Arizona Mountains near Tucson. The people were very friendly, the food was exceptionally good, and the vegetation was most interesting. I had the good fortune to be able to come back to the exact same sites again during the Easter Holidays last spring. Having just finished my lecture on carbon isotope ratios at the time of the first field trip, I was fascinated to see that there were both C_3 and C_4 grasses in this part of the world. For the most part, these sites were grassland ecosystems. I collected all of the grasses growing in a 5 m by 5 m plot at five different sites and took them back to the lab. Once at home in the lab, I ground up the leaves and measured the <u>average</u> carbon isotope ratio ($\delta^{13}C$) for the vegetation on different plots. Remembering that I could get the climate data off the internet, I downloaded the long-term winter and summer climate data. Below is a summary of the data I now have - what a fascinating story this will be when I publish it next year.

Site	$\delta^{13}C$ of plants in winter (‰)	$\delta^{13}C$ of plants in summer (‰)	Total winter rainfall (mm)	Total summer rainfall (mm)	Average temperature in winter (°C)	Average temperature in summer (°C)
1	-27.8	-25	344	420	15	25
2	-23.7	-13	80	460	17	33
3	-28.0	-20	335	400	16	29
4	-27.1	-24	276	386	15	24
5	-26.9	-16	281	460	15	30

1 (15 points). List all sites having summertime vegetation that is greater than 90 % C_4 plants and provide a basis for your answer..

8 points – sites 2 and 5
7 points – explanation
C4 carbon isotope ratios are in the range of -11 to -14 per mil; only two sites have values that fit within this range.

2 (12 points). What is the primary biological driver explaining changes in the observed values of the carbon isotope ratios of vegetation between winter and summer growing seasons? Provide a brief explanation to justify your answer.

6 points – The primary <u>biological</u> driver for the variation in carbon isotope ratios is C3 versus C4 photosynthesis.
6 points – explanation.
C4 plants have isotope ratios in the range of -11 to -14 per mil, whwereas C3 plants have values in the range of -25 to -31 per mil; at each site showing a seasonal change, the shift is towards an increased summertime abundance of C4 plants.

3 (6 points). What is the lightest carbon isotope ratio observed for C_3 vegetation?

6 points - -28 per mil

4 (15 points). Why would you expect to see the observed negative relationship between the carbon isotope ratio of plants in winter and total amount of winter precipitation?

We would expect to see this increase in carbon isotope ratio with decreasing precipitation because stomata close under reduced precipitation resulting in lower ci/ca values. Carbon isotope discrimination decreases with decreasing ci/ca.

5 (12 points). By the way, now I can tell you the rest of the story. The people I was visiting were farmers working on non-irrigated lands. Some farmers were growing wheat and one time of the year, some were growing corn at another time of the year, and others were intercropping both (growing both crops intermixed in the sample plots in the field). Remember that both wheat and corn are grasses. What specific crop(s) were being grown in fields 1 and 5 in each of the different seasons?

Site 1	winter crop = wheat	summer crop = wheat
Site 5	winter crop = wheat	summer crop = corn

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page 487

I have always been fascinated by the hydrological cycle ever since I was a child growing up in Wanship, Utah. The Weber River runs right in front of our old farm and before the Rockport Dam was built we used to get some very large fluctuations in the flow rates from the river as the snowmelt occurred each spring. Much of the water in the Weber River is now used for irrigation. Now having learned about the utility of stable isotope analyses in understanding various aspects of the hydrological cycle, I was keen to go back to the places where I roamed as a child to examine the magnitude of stable isotope ratio variations that I would find in the different components of the hydrological cycle along the Weber River drainage. Last August in the middle of the summer, I collected my water samples for stable isotope ratio analyses. Among the various components of the hydrological cycle that I was able to examine, the following were what I was able to get precise measurements of:

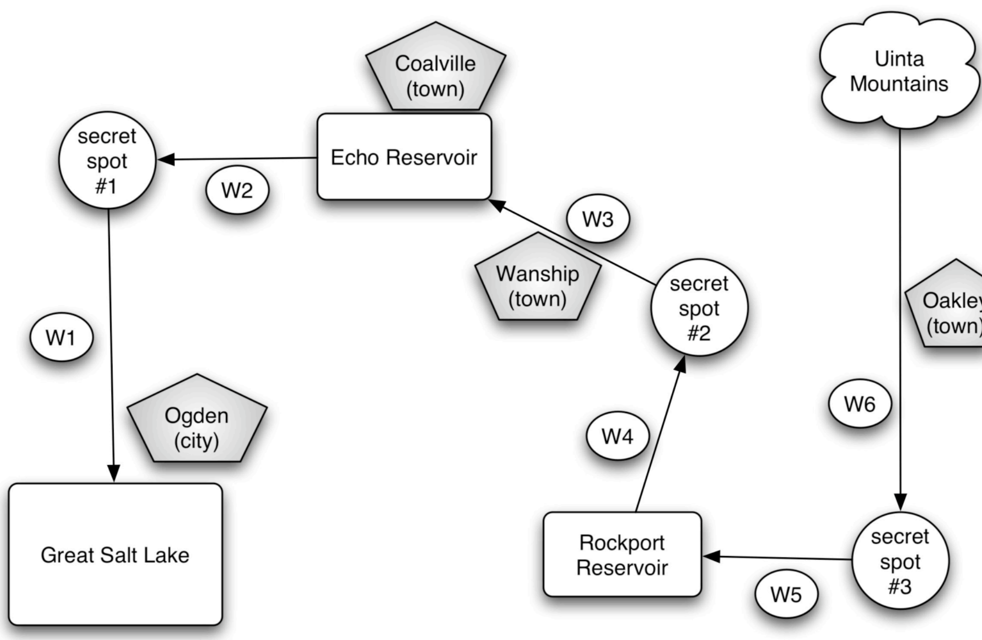
- 1 sample of surface water from the Great Salt Lake
- 1 sample of surface water from Echo Reservoir
- 1 sample of surface water from Rockport Reservoir
- 1 sample of the Weber River near my favorite fishing spot (secret location #1)
- 1 sample of the Weber River near my brother Wilford's secret fishing spot (secret spot #2)
- 1 sample of water from another secret spot
- 6 samples of Weber River water from other locations between the Uinta Mountains and the Great Salt Lake
- 1 sample of well water from our Dad's farm in Wanship

5 (10 points). Do the isotope ratios of the water data presented indicate that there is a reservoir of evaporatively enriched water upstream of the first sample observation? Answer first with a "**yes**" or "**no**" and then provide a justification for your answer below.

5 points – yes or no
5 points – explanation
Depending on whether or not you allocated a value to "Uinta mountains", you can argue that there is or is not a dam upstream. It is the strength of your argument that is used to determine the score.

6 (2 points each). The following water samples are associated with the locations from the lake, reservoir, river, and well sites shown on the map below. There are 12 different river or lake locations and 1 well location. Please match the location letter (i.e., A through N) with a specific geographic region below. Please indicate whether the value of the sample is on the local meteoric water line (yes or no). All data are in "delta" notation relative to the SMOW standard and are expressed in per mil (‰) units.

Location	δ^2H of water, ‰	δ^{18}O of water, ‰	Location on map below	Is the stable isotope ratio of this sample on the local meteoric water line (Y or N)
A	-141	-17.6	**Weber River W5**	**Y**
B	-115	-12.6	**Rockport Reservoir**	**N**
C	-82	-8.9	**Echo Reservoir**	**N**
D	-79	-8.2	**Weber River W1**	**N**
E	-145	-17.8	**Weber River W6**	**Y**
F	-110	-12.2	**Weber River W3**	**N**
G	-110	-12.2	**Wanship well**	**N**
H	-80	-8.7	**secret spot #1**	**N**
J	-143	-17.7	**Secret spot #3**	**Y**
K	-81	-8.8	**Weber River W2**	**N**
L	-111	-12.3	**Secret spot #2**	**N**
M	-48	-1.3	**Great Salt Lake**	**N**
N	-113	-12.4	**Weber River W4**	**N**



7 (6 points). The "well water from our Dad's farm" appears to be right <u>**next to which site**</u> based on similarity of hydrogen and oxygen isotope ratio values?

W3

Page 499

At one time, I was thinking seriously about going to medical school after getting my Biology degree instead of pursuing the botanical career that I ultimately chose. One of the efforts that I did as an undergraduate was to develop predictions of the oxygen isotope ratio of water in human blood. The hard part was how to sample human blood, since I tend to faint when I have to draw blood from a patient. Then a fellow undergraduate pointed out that if I examined the research literature more thoroughly, I would see that the oxygen isotope ratio of water in blood and water in urine for humans were exactly the same. Wow, that saved the day for my research.

Calculating the oxygen isotope ratio of water in human blood ($\delta^{18}O_{blood}$) was rather straight forward, since I took Professor Ehleringer's class. I knew that the oxygen isotope ratios of water in blood were an additive function of only three factors: (a) drinking water ($\delta^{18}O_{drink}$), (b) atmospheric oxygen ($\delta^{18}O_{o2}$), and (c) the carbohydrate source in a person's diet ($\delta^{18}O_{food}$). (I realized that I would have to do my calculations using R values instead of δ values, but that was not a problem).

Having read all those really neat NASA studies on astronauts, I knew that the proportional contributions of drinking water, atmospheric oxygen, and carbohydrate were 0.62, 0.24, and 0.14, respectively.

Remembering from Professor Ehleringer's lectures that the oxygen isotope ratio of atmospheric oxygen was always +23.5‰ (SMOW), it was clear what the oxygen isotope ratio of blood should be.

The equation from the NASA scientists was

$$R_{blood} = (x \bullet R_{drink} + y \bullet 0.992R_{o2} + z \bullet R_{food})/(x + 0.992 \bullet y + 1.038 \bullet z) \qquad \text{Eqn 1}$$

and remembering the basic relationships of

$$\delta^{18}O_{blood} = (R_{blood}/R_{standard} - 1) \bullet 1000‰ \qquad \text{Eqn 2}$$

$$\delta^{18}O_{drink} = (R_{drink}/R_{standard} - 1) \bullet 1000‰ \qquad \text{Eqn 3}$$

$$\delta^{18}O_{food} = (R_{food}/R_{standard} - 1) \bullet 1000‰ \qquad \text{Eqn 4}$$

$$\delta^{18}O_{o2} = (R_{o2}/R_{standard} - 1) \bullet 1000‰ \qquad \text{Eqn 5}$$

$$R_{standard} = 0.0020052 \qquad \text{Eqn 6}$$

$$x + y + z = 1 \qquad \text{Eqn 7}$$

Well, here in the table below are the data I collected that summer as I traveled across the USA collecting drinking water, urine, and food samples.

Location from across the USA	average $\delta^{18}O$ of drinking water, ‰ (SMOW)	average $\delta^{18}O$ of water in urine, ‰ (SMOW)	average $\delta^{18}O$ of carbohydrate food source, ‰ (SMOW)
Salt Lake City, UT	-16.0	-9.7	32
San Diego, CA	-6.0	?	32
Dallas, TX	+1.0	?	32
Miami, FL	-1.0	?	32
West Yellowstone, WY	-19.0	?	32

One of the surprising things I had not initially anticipated before the research and modeling was that the oxygen isotope ratio of water in blood and drinking water did not have not the same values. In fact, the slope was not even 1.0, which initially surprised me.

It was equally surprising that there was far less variation in the oxygen isotope ratios of the food sources than I would have expected. However, since everybody buys their food in a supermarket, perhaps the common values just reflect that the carbohydrates were all grown in the same region of the USA.

8 (10 points). Two of the students were arguing over how to interpret that data. One of the students argues that food was really important in determining the oxygen isotope ratio of water in blood. The other student argues that this was absurd and that atmospheric oxygen had a greater impact than food on determination of the oxygen isotope ratio of water in blood. Who was right and why?

Diatomic oxygen has a greater impact because it contributes 24% of the isotope signal in blood, whereas oxygen from food contributes only 14% of the isotope signal in blood.

9 (14 points). The technicians at a local blood facility have contacted you with a case in which they feel that two blood samples that they have received were inadvertently mislabeled (labels switched). Based on their medical analyses, the blood samples were identical in all biochemical respects. If they cannot correctly identify the origins of the blood samples, the blood must be discarded. What written advice would you give them if the possibly-incorrectly-labeled samples had come from (a) one sample is really from San Diego and one sample is really from Miami **and** (b) both samples are really from Dallas. Your explanations must be clear enough that the technician can make a decision.

(a) Yes, you can tell the difference because the water isotopes differ and water contributes 62% of the of the isotope signal in blood.

(b) No, you cannot determine the difference based on isotopes because both samples should have the same oxygen isotope signal in blood.

10 (16 points). Why is the slope of the relationship between the oxygen isotope ratio of water in blood (y-axis) versus the oxygen isotope ratio of drinking water (x-axis) less than one (1)? A reasonably clear and appropriate length response is required.

The slope of the relationship between the oxygen isotope ratio of water in blood (y-axis) versus the oxygen isotope ratio of drinking water (x-axis)is less than 1 because both food and diatomic oxygen are isotopically heavy relative to tapwater. Thus, as the oxygen isotopes from both food and diatomic oxygen contribute to the oxygen isotope ratio of water in blood, the slope must decrease below a 1:1 line.