

Examination 1
100 points
October 10, 2006

Exam 1 will consist of evaluating and interpreting data from Winston Weatherly's laboratory notebook. All of the data that will be on the exam are provided on the following three pages.

Your response to the actual exam questions (i.e., analyses and interpretations of these data sets) should be based on these data sets, lecture materials presented in class, and reading materials since the previous examination.

You are allowed to work singly or in groups to prepare for the exam. Furthermore, you will be allowed to prepare notes on the following pages of data and bring those materials into the examination on October 10th. No additional materials will be allowed.

Please note.

For the examination, you will have to choose 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

You may choose on your own which to study for now (or maybe even both if you want to keep all of your options open). The examination will have a number of questions related to the data sets. Some of the questions will require that you have analyzed the data beforehand. Other questions will relate to the general topic of the “page”. At the time of the exam, you will be asked to state at the top of the exam, which two pages you wish to be examined on. Obviously this means that the examination will contain exam questions for all three pages.

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 C₃ and C₄ 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 average carbon isotope ratio ($\delta^{13}\text{C}$) 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	$\delta^{13}\text{C}$ of plants in winter (‰)	$\delta^{13}\text{C}$ 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

Here are the different data sets.

Water samples from the lake, reservoir, river, and well. Obviously I screwed up somewhere and forgot to record the locations in my lab notebook. No worries though. I was able to figure it all out based on the hydrologic cycle lectures. All data are in "delta" notation relative to the SMOW standard and are expressed in per mil (‰) units.

Location	$\delta^2\text{H}$ of water, ‰	$\delta^{18}\text{O}$ of water, ‰
A	-141	-17.6
B	-115	-12.6
C	-82	-8.9
D	-79	-8.2
E	-145	-17.8
F	-110	-12.2
G	-110	-12.2
H	-80	-8.7
J	-143	-17.7
K	-81	-8.8
L	-111	-12.3
M	-48	-1.3
N	-113	-12.4

Water samples from the precipitation collected at the farm where I grew up as a child. All data are in "delta" notation relative to the SMOW standard and are expressed in per mil (‰) units.

Precipitation event #	$\delta^2\text{H}$ of precipitation, ‰	$\delta^{18}\text{O}$ of precipitation, ‰
1	-114	-15.0
2	-40	-5.0
3	-130	-17.1
4	-97	-12.7
5	-107	-14.0
6	-96	-12.5
7	-64	-8.3
8	-47	-6.0
9	-56	-7.2
10	-85	-11.0

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 ($\delta^{18}\text{O}_{\text{blood}}$) 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 ($\delta^{18}\text{O}_{\text{drink}}$), (b) atmospheric oxygen ($\delta^{18}\text{O}_{\text{O}_2}$), and (c) the carbohydrate source in a person's diet ($\delta^{18}\text{O}_{\text{food}}$). (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

$$R_{\text{blood}} = (x \cdot R_{\text{drink}} + y \cdot 0.992 \cdot R_{\text{O}_2} + z \cdot R_{\text{food}}) / (x + 0.992 \cdot y + 1.038 \cdot z) \quad \text{Eqn 1}$$

and remembering the basic relationships of

$$\delta^{18}\text{O}_{\text{blood}} = (R_{\text{blood}}/R_{\text{standard}} - 1) \cdot 1000\text{‰} \quad \text{Eqn 2}$$

$$\delta^{18}\text{O}_{\text{drink}} = (R_{\text{drink}}/R_{\text{standard}} - 1) \cdot 1000\text{‰} \quad \text{Eqn 3}$$

$$\delta^{18}\text{O}_{\text{food}} = (R_{\text{food}}/R_{\text{standard}} - 1) \cdot 1000\text{‰} \quad \text{Eqn 4}$$

$$\delta^{18}\text{O}_{\text{O}_2} = (R_{\text{O}_2}/R_{\text{standard}} - 1) \cdot 1000\text{‰} \quad \text{Eqn 5}$$

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

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

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 $\delta^{18}\text{O}$ of drinking water, ‰ (SMOW)	average $\delta^{18}\text{O}$ of water in urine, ‰ (SMOW)	average $\delta^{18}\text{O}$ 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.