



Mississippi Valley Archaeology Center  
1725 State Street  
La Crosse, Wisconsin 54601  
Phone: 608-785-6473  
Web site: <http://mvac.uwlax.edu/>  
Facebook: <https://www.facebook.com/UWLMVAC>



The following lessons were created by **Anna Alinda**, a teacher participating in the National Endowment for the Humanities Summer Institute for Teachers entitled Touch the Past: Archaeology of the Upper Mississippi River Region.

Any views, findings, conclusions or recommendations expressed in this publication do not necessarily represent those of the National Endowment for the Humanities.

### **Isotopic Analysis in Determination of Diet and Migration**

**Subject and Grade Level:** Sophomore Chemistry

#### **Objectives:**

Students will be able to:

- explain the connection between chemistry and archaeology
- infer basic cultural characteristics from archaeological artifacts
- give examples of types of isotopic analysis
- apply isotopic ratio information to patterns in migration and diet of prehistoric peoples
- evaluate the ethics of destructive analysis
- break down academic literature
- interpret graphical data to make conclusions about populations

**Standards (following National Science Standards found here:**

[http://www.nap.edu/openbook.php?record\\_id=4962](http://www.nap.edu/openbook.php?record_id=4962)):

- A.1 Abilities necessary to do scientific inquiry
- A.2 Understandings about scientific inquiry
- B.1 Structure of atoms
- C.4 Populations and ecosystems
- E.2 Understandings about science and technology
- F.1 Personal and community health
- F.2 Populations, resources, and environments
- F.5 Science and technology in society
- G.2 Nature of scientific knowledge

**Duration:**

- 75 minute lesson, 45 minute lesson, 15 minute lesson
- Could also be modified to 45 minute, 30 minute, 45 minute, 15 minute (separating limitations and ethics into a separate lesson).

**Materials/Supplies:**

- *Isotopic Analysis in Archaeology Lesson Document* (referred to as *Lesson document*)
- Worksheets: *Isotopes and Archaeology Worksheet*, *Ethics Worksheet and Reflection*, *Getting the Info Out Worksheet*
- Resources for “Approaching Academic Research” Lesson:
  - Ambrose, Stanley H., Jane Buikstra, and Harold W. Krueger. “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone.” *Journal of Anthropological Archaeology* 22 (2003): 217-226.  
(Available through Science Direct online database)
  - Slater, Philip A., Kristin M. Hedman, and Thomas E. Emerson. “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement.” *Journal of Archaeological Science* 44 (2014): 117-127. Web. 23 July 2014.  
(Available through Science Direct online database)
- Additional resources for background information listed in *Isotopic Analysis in Archaeology Lesson Document*.

**Vocabulary:**

Element

Isotope

Proton

Neutron

Atomic Mass

Migration

C<sub>3</sub> and C<sub>4</sub> Plants

Trophic

Prehistoric

Relative abundance

Standard

δ (delta, difference)

Sampling

Destructive analysis

Repatriation

Kennewick Man

Inference

Outlier

Anomaly

Polity

Vocabulary from resources (see *Isotopic Analysis in Archaeology Lesson Document*)

## **Background**

This lesson is an application of isotopes. For students to be prepared for content, they should be comfortable with isotopes and related skills. In particular, they should know the differences between elements and isotopes of elements. If given a mass number of a specific isotope, students should be able to determine the number of subatomic particles in that isotope. Students should also understand the concept of relative abundance. A very basic understanding of radioactive decay will also be helpful.

## **Setting the Stage**

To set the stage, introduce how chemistry can enrich archaeology. This involves a brief discussion of the field of archaeology, the inferences that can be made, and the information missing from artifacts (without analysis). Short student activity involving what information is missing about school's culture from the garbage bin can clarify gaps in prehistoric data. See *Lesson* document for more detailed plan.

## **Procedure**

After introducing archaeology and the connection to chemistry, begin exploring applications of isotopic analysis in archaeology. Present information about carbon, nitrogen, and strontium isotopes, followed by how this data can provide information about diet and migration. After approaching the issue technically, a discussion of limitations and ethical concerns will set the stage for student assignment (Ethics Reflection). Finally, academic research on the topics can be used to introduce students to the skills necessary to tackle high level published research. Beginning as a class, together students and instructor can dissect the more complicated elements, eventually moving into data interpretation and small group work. See *Lesson* document for more detailed plan.

## **Closure**

Closure lesson revisits ethics to discuss conclusions as a class. Prompt questions are included in *Lesson* document.

## **Evaluation**

There are three worksheets attached, each with an answer key. Additionally, there is a basic rubric included for the Ethics Reflection writing prompt. Concepts from this unit can be included in the general assessment for the Chapter including isotopes.

## **Links/Extension**

Many background resource links are included in *Lesson* document.

Extensions could include:

- further discussion of the history of rights of indigenous peoples
- radioactivity lesson (including radiocarbon dating)
- discussion of calibration of radiocarbon dates
- associated lesson on the science of archaeology conservation

**References**

See Materials/Supplies

**Attachments**

- *Isotopic Analysis in Archaeology Lesson Document*
- *Worksheets: Isotopes and Archaeology Worksheet, Ethics Worksheet and Reflection, Getting the Info Out Worksheet*

## Isotopic Analysis in Archaeology Lesson Document

### Necessary Skills:

This lesson is an application of isotopes. For students to be prepared for content, they should be comfortable with isotopes and related skills. In particular, they should know the differences between elements and isotopes of elements. If given a mass number of a specific isotope, students should be able to determine the number of subatomic particles in that isotope. Students should also understand the concept of relative abundance. A basic understanding of radioactive decay will also be helpful.

### Lesson 1 – Introduction and Specific Applications (75 minutes)

1. How can chemistry enrich archaeology?
  - What is archaeology?
  - Observations and inferences in archaeology
    - e.g. observation: stone materials are found far from sources, inference: Archaic people are trading with one another
  - Data that cannot necessarily be observed
    - have students generate list of what information cannot be learned about the school from its garbage
    - bring up difference between cultures with written record and permanent dwellings vs. prehistoric cultures with structures that would not survive
    - discuss materials that most often would not survive being buried (e.g. wood, paper, fabric, plant remains)
  - Chemical processes that can provide more data
    - radiocarbon dating
    - isotopic analysis
    - organic residue analysis
    - material analyses (e.g. pottery, glazes, pigments)
  - Preserving materials by chemical means
    - cleaning
    - treating corrosion of metals
    - marine artifacts

Resources for background information:

Introduction to Archaeological Chemistry

<http://pubs.acs.org/doi/pdf/10.1021/ba-1978-0171.ch001> (older source, but good introduction)

Short Royal Society of Chemistry Article

<http://www.rsc.org/chemistryworld/Issues/2008/October/TheInsiderArchaeologicalInvestigation.asp>

Lambert, Joseph B. *Traces of the Past*. Cambridge: Perseus Publishing, 1997.

Pollard, A. M., et al. *Analytical Chemistry in Archaeology*. Cambridge: Cambridge UP, 2007.

## 2. Why isotopes?

- isotopic analyses can measure certain isotopes (or isotope ratios) in provided samples
- recall relative abundance – while we have been able to calculate an overall percentage for earth, the relative abundance often varies between locations on earth
- these analyses can be applied to provide information about diet and migration (and more!)

Resources for background information:

Isotope Analyses from Simon Fraser University Museum Website

[http://www.sfu.museum/forensics/eng/pg\\_media-media\\_pg/isotopes/](http://www.sfu.museum/forensics/eng/pg_media-media_pg/isotopes/)

Archaeology Magazine Abstract about Strontium Isotopes

<http://archive.archaeology.org/0705/abstracts/isotopes.html>

University of South Florida Department of Archaeology Isotopes and Diet

<http://luna.cas.usf.edu/~rtykot/PR39 - Enrico Fermi isotopes.pdf>

Price, T. Douglas, and James H. Burton. *An Introduction to Archaeological Chemistry*. New York: Springer, 2011.

### A. Isotope ratios: Strontium and migration

- strontium is an element for which isotope ratios vary based on location
- strontium has four stable naturally occurring isotopes: strontium-84, strontium-86, strontium-87 and strontium-88
- overall, relative abundances on earth are:  $^{84}\text{Sr}$  (0.56%),  $^{86}\text{Sr}$  (9.86%),  $^{87}\text{Sr}$  (7.0%) and  $^{88}\text{Sr}$  (82.58%)
- however, strontium-87 can be produced from radioactive decay of  $^{87}\text{Rb}$
- scientists look at the  $^{87}\text{Sr}/^{86}\text{Sr}$  in geological and archaeological measurements for local variance (the ratio is different for different types and ages of rock)
- helpful for archaeologists because strontium is stored in bones and teeth
- when enamel forms, the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio is fixed
- scientists can compare  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in teeth that formed at different times to identify if teeth formed in different geographical locations
- can use strontium data to gather information about people's movement

Resources for background information:

Wikipedia pages for isotope analysis, strontium isotopes and tooth development

[http://en.wikipedia.org/wiki/Isotope\\_analysis](http://en.wikipedia.org/wiki/Isotope_analysis)

[http://en.wikipedia.org/wiki/Isotopes\\_of\\_strontium](http://en.wikipedia.org/wiki/Isotopes_of_strontium)

[http://en.wikipedia.org/wiki/Tooth\\_development](http://en.wikipedia.org/wiki/Tooth_development)

### B. Isotope ratios: Carbon and nitrogen

- carbon has three naturally occurring isotopes: carbon-12, carbon-13, and carbon-14 (carbon-14 is radioactive and will decay)
- overall, the relative abundances on earth are:  $^{12}\text{C}$  (98.9%),  $^{13}\text{C}$  (1.1%) and  $^{14}\text{C}$  (trace)
- but how can carbon tell us about diet?
- maize (corn) has a different photosynthetic pathway than most other plants

- while most plants first convert carbon dioxide to 3-carbon compounds ( $C_3$ ), tropical plants like maize convert carbon dioxide first to 4-carbon compounds ( $C_4$ )
- $C_3$  and  $C_4$  plants will have different  $^{12}C/^{13}C$  ratios, which are absorbed by the organisms that eat them ( $C_4$  have more  $^{13}C$ )
- the  $^{12}C/^{13}C$  ratio will be preserved in bone of animals and humans
- scientists use a standard to set the ratio (limestone) and measure the difference from the standard
- the notation is often a negative percent (e.g.  $\delta^{13}C$  -12.5%)
- $C_3$  plants will have more negative  $\delta^{13}C$  values, and  $C_4$  plants will have less negative  $\delta^{13}C$  values – high corn diets should be reflected by less negative  $\delta^{13}C$  values
- nitrogen has two naturally occurring stable isotopes: nitrogen-14 and nitrogen-15
- overall, the relative abundances on earth are:  $^{14}N$  (99.643%) and  $^{15}N$  (0.366%)
- like carbon, ratios of  $^{15}N/^{14}N$  can provide information about diet
- a more positive nitrogen isotope ratio reflects a higher trophic level (higher on the food chain) – more positive nitrogen isotope ratio means more of a carnivore

Resources for background information:

Price, T. Douglas, and James H. Burton. *An Introduction to Archaeological Chemistry*. New York: Springer, 2011.

Wikipedia pages for carbon, nitrogen, trophic level

<http://en.wikipedia.org/wiki/Carbon>

<http://en.wikipedia.org/wiki/Nitrogen>

[http://en.wikipedia.org/wiki/Trophic\\_level](http://en.wikipedia.org/wiki/Trophic_level)

Pima Community College Types of Photosynthesis

[http://wc.pima.edu/~bfiero/tucsonecology/plants/plants\\_photosynthesis.htm](http://wc.pima.edu/~bfiero/tucsonecology/plants/plants_photosynthesis.htm)

### 3. Limitations and considerations

- For migration: Multiple movements over lifetime
- For carbon: marine life also means more  $^{13}C$
- For all: Process of decay needs to be fully understood to factor in changes to material over time.

### 4. Ethics of sampling and destructive analysis

- to gain isotopic information, need to remove sample of bone and destroy it during the analysis
- ethical question of destroying human remains: no longer available for future analysis
- generally, does information gained justify destruction of sample?
- ethical question of disturbing human remains (if someone wanted to dig up my grandma, I might have some problems with that)
- United Nations Declaration on the Rights of Indigenous Peoples, The Native American Graves Protection and Repatriation Act (NAGPRA)

- what considerations need to be made?
- which is more important, ethics or information?

Resources for background information:

Archaeological Ethics Documents from Advisory Panel on the Archaeology of Burials in England

[http://www.archaeologyuk.org/apabe/Science\\_and\\_the\\_Dead.pdf](http://www.archaeologyuk.org/apabe/Science_and_the_Dead.pdf) Text

of United Nations Declaration on the Rights of Indigenous Peoples

<http://www.ohchr.org/Documents/Issues/IPeoples/UNDRIPManualForNHRIs.pdf>

Wikipedia pages for UN Declaration on the Rights of Indigenous Peoples and NAGPRA

[http://en.wikipedia.org/wiki/Declaration\\_on\\_the\\_Rights\\_of\\_Indigenous\\_Peoples](http://en.wikipedia.org/wiki/Declaration_on_the_Rights_of_Indigenous_Peoples)

[http://en.wikipedia.org/wiki/Native\\_American\\_Graves\\_Protection\\_and\\_Repatriation\\_Act](http://en.wikipedia.org/wiki/Native_American_Graves_Protection_and_Repatriation_Act)

NAGPRA Text from National Park Service

<http://www.nps.gov/nagpra/MANDATES/25USC3001etseq.htm>

Burke Museum Kennewick Man Website

<http://www.burkemuseum.org/kennewickman>

*Homework: Isotopes and Archaeology Worksheet, Ethics Worksheet and Reflection Assignment*

## **Lesson 2 – Approaching Academic Research (45 minutes)**

### 5. Reading an academic paper (together as a class)

- **Resource:** Ambrose, Stanley H., Jane Buikstra, and Harold W. Krueger. “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone.” *Journal of Anthropological Archaeology* 22 (2003): 217-226. (Available through Science Direct online database)
- as a class, read paragraph by paragraph through first four paragraphs of paper
- pull out vocabulary and terms for students to look up (e.g. mounds, pre-Columbian, periphery, hierarchical complexity, pathologies, non-metric, etc.)
- use footnote #2 to demonstrate using footnotes for clarification and data
- discuss important information for comprehension (e.g. C<sub>3</sub> and C<sub>4</sub> pathway information)
- Focus on sentences that will drive how data could support inferences
  - e.g. “If low status individuals had limited access to high quality foods[...] they should have less negative  $\delta^{13}\text{C}$  values than high status individuals” (218)

### 6. Interpreting Data

- Again using “Status and gender difference in diet at Mound 72” paper, present Figure 1 and Table 1.
- Discuss again meanings of N and C data for the Figure 1 and Table 1. Have students make notations on data charts.
- Discuss outliers and anomalies.



- Putting students in groups, have them complete first 6 questions on *Getting out the Info* Worksheet based on those tables.
7. Reading an academic paper (in groups)
- **Resource:** Slater, Philip A., Kristin M. Hedman, and Thomas E. Emerson. “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement.” *Journal of Archaeological Science* 44 (2014): 117-127. Web. 23 July 2014. (Available through Science Direct online database.)
  - Have students replicate process from class reading, highlighting and researching new terms
  - Have students read through paragraph 8 (“... to provenance studies.” p.118)
  - Using Figure 3, Figure 5 and Figure 6, have students complete *Getting out the Info* Worksheet for homework.

*Homework: Getting the Info Out Worksheet*

### **Lesson 3 - Closure activity (15 minutes)**

Tally student responses from Ethics Reflection after collected and graded. Show students the response distribution and have a small discussion. The following questions may be useful in facilitating discussion.

- Is it important for us to know about prehistoric peoples? Why or why not?
- Who counts as an “ancestor”? How far back can that association go?
- How do we know all that we know about prehistoric burials? (Might be necessary to remind date that NAGPRA was put into effect.)
- Is it possible to have a balance between respecting repatriation and gaining information?
- In the Kennewick Man legal battle, who would you rather be a lawyer for: a Native American tribe or the scientists?
- Is there any time when information is more important than respecting people’s beliefs?

Name: \_\_\_\_\_ Date: \_\_\_\_\_

Isotopes and Archaeology Worksheet

1. For each of the isotopes below, determine the values.

a. Strontium-87

# Protons: \_\_\_\_\_

#Neutrons: \_\_\_\_\_

# Electrons: \_\_\_\_\_

b. Carbon-13

Mass #: \_\_\_\_\_

#Neutrons: \_\_\_\_\_

Atomic #: \_\_\_\_\_

c. Nitrogen-15

# Protons: \_\_\_\_\_

#Neutrons: \_\_\_\_\_

Mass #: \_\_\_\_\_

2. Two samples of bone from an archaeological site are analyzed for nitrogen isotope ratio. The first sample, from a lower ranking individual, has a  $\delta^{15}\text{N}$  of 1.4%, while the second sample, from a higher ranking individual, has a  $\delta^{15}\text{N}$  of 8.7%. Based on only this data, mark whether each conclusion is correct, incorrect, or based on insufficient data.

a. The lower ranking individual never ate meat.

\_\_\_\_\_

b. The higher ranking individual ate more meat than the lower ranking individual.

\_\_\_\_\_

c. Meat was expensive.

\_\_\_\_\_

d. Both individuals ate similar amounts of meat.

\_\_\_\_\_

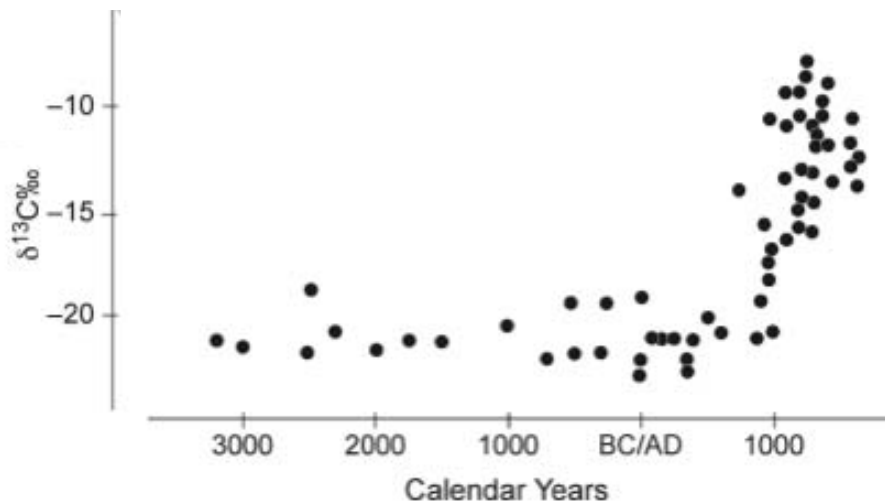
Continue to back of page!

Based on the following data for five burials from the same site, answer questions #3-6. The strontium ratio range for the location in which the burial was located is 0.719 – 0.730.

Sr Ratios	Burial 1	Burial 2	Burial 3	Burial 4	Burial 5
First molar	0.725	0.760	0.709	0.706	0.720
Second molar	0.744	0.722	0.755	0.712	0.727
Third molar	0.730	0.727	0.722	0.709	0.721

- Which individual spent his/her entire life in the same area in which they were buried?
- Which individuals were born (using first molar as birth location) in a location different than the one in which they were buried?
- Which individual moved to the location in which they were buried late in life (after the formation of the third molar)?
- Which individual lived in a different location than the one in which he/she was buried only during the formation of the second molar?

Using your notes and the following graph, answer questions #7-10.



- According to your notes, a more negative  $\delta^{13}\text{C}$  value represents a \_\_\_\_\_ corn diet.
- The following two  $\delta^{13}\text{C}$  values represent a low corn and a high corn diet. Which represents low corn and which represents high corn?
  - $\delta^{13}\text{C} = -27.5\%$  \_\_\_\_\_
  - $\delta^{13}\text{C} = -10.6\%$  \_\_\_\_\_
- At roughly what date did corn become a more significant staple in human diet?

## TEACHER'S KEY

### Isotopes and Archaeology Worksheet

1. For each of the isotopes below, determine the number of subatomic particles.
  - a. Strontium-87
    - # Protons: 38
    - #Neutrons: 49
    - # Electrons: 38
  - b. Carbon-13
    - Mass #: 13
    - # Neutrons: 7
    - Atomic #: 6
  - c. Nitrogen-15
    - # Protons: 7
    - #Neutrons: 8
    - Mass #: 15
2. Two samples of bone from an archaeological site are analyzed for nitrogen isotope ratio. The first sample, from a lower ranking individual, has a  $\delta^{15}\text{N}$  of 1.4%, while the second sample, from a higher ranking individual, has a  $\delta^{15}\text{N}$  of 8.7%. Based on only this data, mark whether each conclusion is correct, incorrect, or based on insufficient data.
  - a. The lower ranking individual never ate meat.  
Insufficient data – no data provided about what % shows conclusive meat consumption
  - b. The higher ranking individual ate more meat than the lower ranking individual.  
Correct
  - c. Meat was expensive.  
Insufficient data – no data provided about cost. Possibly a reasonable conclusion based on high ranking individuals' consumption, but could be ritual instead of economic.
  - d. Both individuals ate similar amounts of meat.  
Incorrect – if correct we would not see such variance in  $\delta^{15}\text{N}$

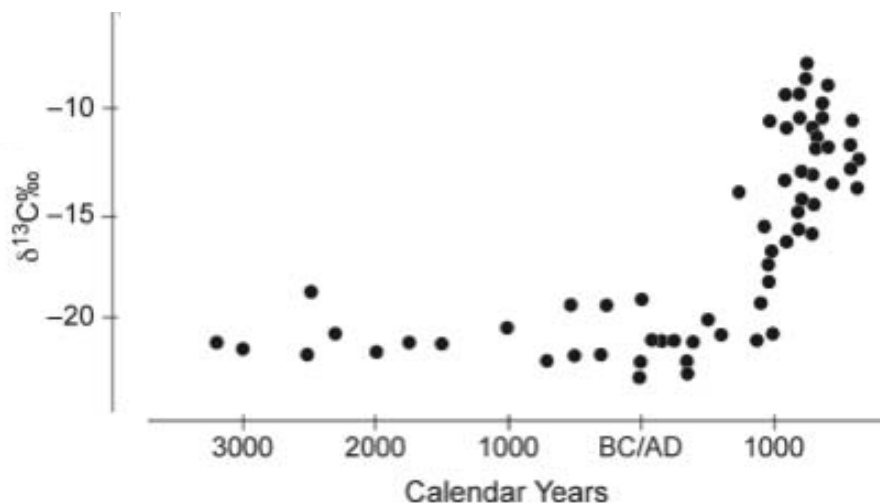
Continue to back of page!

Based on the following data for five burials from the same site, answer questions #3-6. The strontium ratio range for the location in which the burial was located is 0.719 – 0.730.

Sr Ratios	Burial 1	Burial 2	Burial 3	Burial 4	Burial 5
First molar	0.725	0.760	0.709	0.706	0.720
Second molar	0.744	0.722	0.755	0.712	0.727
Third molar	0.730	0.727	0.722	0.709	0.721

- Which individual spent his/her entire life in the same area in which they were buried? **Burial 5**
- Which individuals were born (using first molar for birth location) in a location different than the one in which they were buried? **Burials 2 and 3**
- Which individual moved to the location in which they were buried late in life (after the formation of the third molar)? **Burial 4**
- Which individual lived in a different location than the one in which he/she was buried only during the formation of the second molar? **Burial 1**

Using your notes and the following graph, answer questions #7-10.



- According to your notes, a more negative  $\delta^{13}\text{C}$  value represents a **low** corn diet.
- The following two  $\delta^{13}\text{C}$  values represent a low corn and a high corn diet. Which represents low corn and which represents high corn?
  - $\delta^{13}\text{C} = -27.5\%$  **low corn**
  - $\delta^{13}\text{C} = -10.6\%$  **high corn**
- At roughly what date did corn become a more significant staple in human diet? **1000 AD**

Name: \_\_\_\_\_ Date: \_\_\_\_\_  
Ethics Worksheet and Reflection

An excerpt from United Nations Declaration on the Rights of Indigenous Peoples:

*Indigenous peoples have the right to manifest, practise [sic], develop and teach their spiritual and religious traditions, customs and ceremonies; the right to maintain, protect, and have access in privacy to their religious and cultural sites; the right to the use and control of their ceremonial objects; and the right to the repatriation of their human remains.<sup>1</sup>*

An excerpt from “The Native American Graves Protection And Repatriation Act: The Death Knell for Scientific Study?”

*In enacting NAGPRA, Congress attempted to "strike a balance between the interest in scientific examination of skeletal remains and the recognition that Native Americans, like people from every culture around the world, have a religious and spiritual reverence for the remains of their ancestors." <sup>2</sup>*

Quick research:

1. Define repatriation.
2. What is the meaning of [sic] within a quote?
3. When was the UN Declaration adopted?
4. On what date did NAGPRA go into effect in the US?

In 1996, a controversial skeleton was discovered in Kennewick, WA. Modern tribes claimed the remains, but scientific study concluded that Kennewick Man was over 9,000 years old. Some argue that this places him as too distant an ancestor to connect to any modern tribe, while others say his location is evidence enough of ancestry. After reading through the excerpts above and doing some basic research online, make an argument for what should happen to Kennewick Man. Do you think the remains should be returned to Native American tribes for reburial? Or do you believe the remains should be kept by the US government and used for scientific research? Justify your answer with at least two full paragraphs. Your work should reference the materials above and include information from at least one online or print source. Include a bibliography, and be sure to indicate direct quotes.

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<sup>1</sup> “United Nations Declaration on the Rights of Indigenous Peoples.” United Nations: 2008. Web. 28 August 2014 < [http://www.un.org/esa/socdev/unpfii/documents/DRIPS\\_en.pdf](http://www.un.org/esa/socdev/unpfii/documents/DRIPS_en.pdf)>

<sup>2</sup> Renee Kosslak, “The Native American Graves Protection And Repatriation Act: The Death Knell For Scientific Study?”, 24 American Indian Law Review 129-151, 129-133, 151 (2000)

Name: \_\_\_\_\_

Ethics Worksheet and Reflection Rubric

Quick Research Questions	_____ / 5
Argument: Thoughtful, researched, solid argument	_____ / 15
Content: Shows understanding of ethical question	_____ / 15
Length	_____ / 5
Citation: MLA format, direct quotes	_____ / 10
TOTAL:	_____ / 50

Name: \_\_\_\_\_

Ethics Worksheet and Reflection Rubric

Quick Research Questions	_____ / 5
Argument: Thoughtful, researched, solid argument	_____ / 15
Content: Shows understanding of ethical question	_____ / 15
Length	_____ / 5
Citation: MLA format, direct quotes	_____ / 10
TOTAL:	_____ / 50

Name: \_\_\_\_\_

Ethics Worksheet and Reflection Rubric

Quick Research Questions	_____ / 5
Argument: Thoughtful, researched, solid argument	_____ / 15
Content: Shows understanding of ethical question	_____ / 15
Length	_____ / 5
Citation: MLA format, direct quotes	_____ / 10
TOTAL:	_____ / 50

Name: \_\_\_\_\_ Date: \_\_\_\_\_  
Getting Out the Info – Reading Academic Journal Articles

Using “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone”<sup>3</sup> (online), answer the following questions.

1. Based on Figure 1, which type of individual (high status or low status) consumed the most meat?
2. The outliers of each status group are indicated by their burial number. What is the burial number of the high status outlier?
3. Generally, which type of individual (high status or low status) consumed more corn?
4. According to Table 1, how many burials were contained in Feature 219?
5. What is the average  $\delta^{15}\text{N}$  of all high status individuals?
6. For high status individuals, two means are provided. Why did researchers provide an average that excludes Burial 120?

Using “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement”<sup>4</sup> (online), answer the following questions.

7. According to Figure 3, which location (see list of locations in right-hand box of Figure 3) contains the most significant outlier?
8. Which of the following locations contained an individual with a strontium isotope outside the accepted Cahokia range? (Choose all correct answers.)
  - a. Tract 15 B
  - b. E. St. Louis
  - c. Powell Md. 84
  - d. Powell Md. 86
  - e. Sawmill
  - f. G.E.M. Store
  - g. Pittsburgh Lake

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3 Ambrose, Stanley H., Jane Buikstra, and Harold W. Krueger. “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone.” *Journal of Anthropological Archaeology* 22 (2003): 217-226.

4 Slater, Philip A., Kristin M. Hedman, and Thomas E. Emerson. “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement.” *Journal of Archaeological Science* 44 (2014): 117-127. Web. 23 July 2014.



9. Which of the following locations contained more individuals with strontium isotope ranges outside the accepted Cahokia range than individuals within the accepted range? (Only one correct answer.)
  - a. Fingerhut
  - b. Powell Md. 84
  - c. James Ramey
  
10. Figure 5 shows data for pairs of teeth from the same individual. The pairs are plotted along the x-axis, meaning two data points on x=1 represent two teeth from the same individual. Using pair number to identify individuals, which individuals from Mound 72 contained teeth with strontium ratios outside the Cahokia range?
  
11. Reading through the Figure 5 caption, you can conclude that three individuals did not move from Cahokia in their lifetime. Using pair numbers, list those individuals.
  
12. Based on strontium isotope ratios in paired teeth, which two pairs indicate movement between Cahokia and an area with a significantly different strontium isotope ratio? (Hint: look for points that could be outliers.)
  
13. Examining Figure 6, which two locations had individuals with the highest difference between strontium isotope ratios?
  
14. How many individuals have a  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio between 0.00060-0.00090?

## TEACHER'S KEY

### Getting Out the Info – Reading Academic Journal Articles

Using “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone.”<sup>5</sup>

1. Based on Figure 1, which type of individual (high status or low status) consumed the most meat?  
**high status**
2. The outliers of each status group are indicated by their burial number. What is the burial number of the high status outlier?  
**120**
3. Generally, which type of individual (high status or low status) consumed more corn?  
**low status**
4. According to Table 1, how many burials were contained in Feature 219?  
**2**
5. What is the average  $\delta^{15}\text{N}$  of all high status individuals?  
**9.9**
6. For high status individuals, two means are provided. Why did researchers provide an average that excludes Burial 120?  
**Burial 120 is an outlier**

Using “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement.”<sup>6</sup>

7. According to Figure 3, which location (see list of locations in right-hand box of Figure 3) contains the most significant outlier?  
**Fingerhut**
8. Which of the following locations contained an individual with a strontium isotope outside the accepted Cahokia range? (Choose all correct answers.)
  - a. Tract 15 B
  - b. **E. St. Louis**
  - c. Powell Md. 84
  - d. Powell Md. 86
  - e. **Sawmill**
  - f. **G.E.M. Store**
  - g. Pittsburgh Lake

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<sup>5</sup> Ambrose, Stanley H., Jane Buikstra, and Harold W. Krueger. “Status and gender differences in diet at Mound 72, Cahokia, revealed by isotopic analysis of bone.” *Journal of Anthropological Archaeology* 22 (2003): 217-226.

<sup>6</sup> Slater, Philip A., Kristin M. Hedman, and Thomas E. Emerson. “Immigrants at the Mississippian polity of Cahokia: strontium isotope evidence for population movement.” *Journal of Archaeological Science* 44 (2014): 117-127. Web. 23 July 2014.

9. Which of the following locations contained more individuals with strontium isotope ranges outside the accepted Cahokia range than within the accepted range? (Only one correct answer.)
- Fingerhut
  - Powell Md. 84
  - James Ramey
10. Figure 5 shows data for pairs of teeth from the same individual. The pairs are plotted along the x-axis, meaning two data points on x=1 represent two teeth from the same individual. Using pair number to identify individuals, which individuals from Mound 72 contained teeth with strontium ratios outside the Cahokia range?
- Pairs 3, 6, 8, 22, 24, 26
11. Reading through the Figure 5 caption and examining the data points on the graph, you can conclude that three individuals did not move from Cahokia in their lifetime. Using pair numbers, list those individuals. Be sure to check your pair numbers from the caption with the graphical data.
- Pairs 10, 25, 40 (if students list 24, 43, 44, note that those ranges are outside the strontium ratio for Cahokia)
12. Based on strontium isotope ratios in paired teeth, which two pairs indicate movement between Cahokia and an area with a significantly different strontium isotope ratio? (Hint: look for points that could be outliers.)
- Pairs 29 and 30
13. Examining Figure 6, which two locations had individuals with the highest difference between strontium isotope ratios?
- Submound 51 and Powell Md. 86-BP
14. How many individuals have a  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio between 0.00060-0.00090?
- 5