NO PREP

Isotope Analysis

You Are What You Eat (and Where You Lived)

Includes: Student reading, case study, differentiated questions, teacher key

Name: Period: Date:

Isotope Analysis: You Are What You Eat (and Where You Lived)

What Are Isotopes and Why Do They End Up in Bones?

Every chemical element exists in multiple forms called isotopes — versions of the same element with the same number of protons but different numbers of neutrons. Most isotopes are stable, meaning they do not decay radioactively. Because different isotopes of the same element have slightly different masses, living organisms incorporate them into their tissues at different rates depending on diet and environment. Over the course of a lifetime, the isotopes an animal or person consumes through food and water become literally incorporated into the molecules of their bones and teeth — and when those bones are preserved for centuries or millennia, the isotopic signatures they contain can be analyzed by archaeologists to reconstruct

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Strontium: The Geographic Tracker

Strontium isotope analysis is perhaps the most powerful tool for reconstructing geographic mobility. Strontium is a naturally occurring element found in soil and water, and its isotopic ratio varies predictably across different geological formations. Plants absorb strontium from the soil they grow in. Animals and humans absorb strontium from the plants and water they consume. That strontium is then

incorporated into tooth enamel as it forms during childhood. Once enamel is formed, it does not remodel or change. This means that the strontium ratio in a person's tooth enamel is a permanent record of the geology of the region where they spent their childhood, regardless of where they later moved or where they were buried. This has made strontium analysis a powerful tool for identifying migrants in ancient burial populations. If a skeleton is found in a Roman cemetery in England but its tooth enamel strontium signature matches the geology of North Africa rather than Britain, that person almost certainly did not grow up in England. Strontium analysis has revealed that Roman cities were far more cosmopolitan than traditional historical accounts suggested, with individuals buried in the same cemeteries having grown up in locations spanning from Scotland to the Sahara.

Carbon and Nitrogen: Reading Ancient Diets

While strontium tracks where you lived, carbon and nitrogen isotopes track what you ate. Different types of plants fix carbon differently during photosynthesis. C3 plants, which include wheat, barley, most European crops, and the majority of temperate-zone vegetation, have a lower ratio of carbon-13 to carbon-12 than C4 plants, which include maize, sorghum, and millet. Because these isotopic signatures pass up the food chain, the carbon isotope ratio in human collagen (extracted from bone) reflects the proportion of C3 versus C4 plants in a person's diet. This allowed researchers to track the adoption of maize agriculture across the Americas by measuring when carbon isotope ratios in human bone shifted toward C4 values. Nitrogen isotopes work differently: their ratio in bone collagen reflects an individual's position in the food chain. Nitrogen-15 becomes enriched at each trophic level, meaning that carnivores have higher nitrogen-15 ratios than herbivores, and humans who ate large amounts of animal protein have higher ratios than those who subsisted primarily on plant foods. In coastal populations, marine protein (from fish and shellfish) produces particularly elevated nitrogen-15 ratios because ocean food chains are longer than terrestrial ones. This allows researchers to distinguish, for example, whether inland prehistoric peoples were primarily farmers or relied heavily on fishing.

Famous Cases: When Isotopes Exposed the Truth

Some of the most compelling applications of isotope analysis have overturned longstanding historical assumptions. The 'Amesbury Archer,' a wealthy Bronze Age

burial found near Stonehenge, was found through strontium analysis to have grown up in the Alpine region of central Europe — not in Britain, as his burial location implied. This finding suggested that skilled craftsmen and elite individuals traveled long distances in Bronze Age Europe, a level of mobility that many scholars had not previously appreciated. Richard III, whose skeleton was discovered beneath a Leicester car park in 2012, had his isotopes analyzed along with his bones. The results showed that his nitrogen and carbon ratios shifted significantly in the years before his death at the Battle of Bosworth in 1485, consistent with a dramatically richer diet — more game, more freshwater fish, more exotic foods — in the years when he was king. Isotopes captured not just where he grew up but the material transformation of his life as he rose to power. These are not historical records or written accounts — they are the chemical signatures of a life, preserved in bone.

Key Information: Isotope Analysis

Isotope Type	Element	What It Tracks	Sample Material Used
Strontium (87Sr/86Sr)	Strontium	Geographic origin — geology of childhood environment	Tooth enamel (permanent, forms in childhood)
Carbon (13C/12C)	Carbon	Diet — C3 vs. C4 plant consumption; marine vs. terrestrial food	Bone collagen
Nitrogen (15N/14N)	Nitrogen	Trophic level — proportion of animal protein in diet	Bone collagen
Oxygen (18O/16O)	Oxygen	Climate and water sources — tracks geographic movement	Tooth enamel, bone

Isotope Type	Element	What It Tracks	Sample Material Used
Amesbury Archer case	Strontium	Proved Bronze Age elite migrated from Alpine Europe to Britain	Tooth enamel
Richard III case	Carbon/Nitrogen	Showed dramatic dietary enrichment when he became king	Bone collagen
Maize adoption tracking	Carbon	Shift from C3 to C4 ratios marks when maize became a diet staple	Bone collagen
Roman cosmopolitanism	Strontium	York cemetery individuals with North African/Mediterranean isotope signatures	Tooth enamel

Case Study: The Stranger in the York Cemetery

Tomas Reyes has been a bioarchaeologist for eleven years, and he has excavated Roman cemeteries in three countries. But skeleton EBR-14, from a Roman-period burial ground on the outskirts of York, England, has been sitting in his lab for two months now, and he keeps returning to the isotope results. The strontium ratio from the tooth enamel does not match local British geology. It does not match anywhere in northern Europe. The values cluster most closely with geological signatures from the North African coast — modern Morocco or Algeria. This individual, buried in Roman-era York with a bronze fibula clasp and a small oil lamp, grew up somewhere near the Sahara. Tomas runs the data again. Same result. He pulls up the burial record. EBR-14 is biologically male, estimated age 35-45 at death, with skeletal markers consistent with a physically active lifestyle — significant enthesopathies in the arms and legs. A soldier, perhaps. Or a merchant. Or a craftsman who followed the Roman army north. 'This is the thing about Rome,' he tells his undergraduate research assistant, who is helping enter the data. 'We think of it as a British or Italian story. But Roman York was genuinely international. This man walked around the streets of Eboracum having grown up on a completely different continent.' He pauses. 'The bones know things the history books forgot.'

1. Using the reading passage, explain exactly what the strontium isotope data tells Tomas about skeleton EBR-14 — and why tooth enamel specifically is used for this type of analysis.

2. How does Tomas's discovery support or complicate the traditional picture of Roman Britain? Use both the case study and the reading to support your answer.

Multiple Choice

1. Why is tooth enamel preferred over bone for strontium isotope analysis?

    a) Tooth enamel forms in childhood and does not remodel, preserving the isotopic signature of early life

    b) Tooth enamel contains more strontium than any other tissue in the body

    c) Bone collagen breaks down too quickly for strontium to be reliably measured in any laboratory analysis

    d) Strontium is found only in the enamel layer and is absent from bone tissue

2. What does a high nitrogen-15 ratio in ancient bone collagen indicate?

    a) The individual experienced malnutrition during childhood

    b) The individual consumed significant amounts of animal protein

    c) The individual grew up in a coastal environment with high humidity

    d) The individual consumed a diet high in C4 plants such as maize

3. What did isotope analysis of the Amesbury Archer reveal?

    a) He had a diet dominated by marine fish from the English Channel

    b) He was born and raised near Stonehenge, confirming local elite status

    c) He grew up in the Alpine region of central Europe, not in Britain

    d) His nitrogen ratios showed he was likely a vegetarian farmer

Matching

Write the letter of the correct definition on the line next to each term.

Term	Definition
1. ___ Isotope analysis	A) Isotope ratio in bone collagen that distinguishes C3 plant diets from C4 plant diets
2. ___ Strontium	B) Scientific technique using ratios of elemental variants in bone to reconstruct diet and origin
3. ___ Carbon isotope	C) Hard dental tissue that forms in childhood and preserves isotopic signatures permanently
4. ___ Nitrogen isotope	D) Element whose isotopic ratio in tooth enamel records the geology of a person's childhood home
5. ___ Tooth enamel	E) Isotope ratio in bone collagen that reflects trophic level and animal protein consumption

Fill-in-the-Blank

1. _____ isotopes in tooth enamel can reveal where a person grew up based on the geology of their childhood environment.

2. Carbon isotopes in bone collagen distinguish between diets based on C3 plants, like wheat, and C4 plants like _____, which was a staple crop in the Americas.

3. Because tooth enamel forms in childhood and never _____, it preserves a permanent record of a person's geographic origin.

Short Answer

Answer each question in 2-4 complete sentences.

1. Why do archaeologists prefer tooth enamel over bone for geographic isotope analysis, and what does this tell us about how bones change throughout life?

2. How did isotope analysis change our understanding of the Roman Empire's population, and what specific type of isotope analysis was most useful for this?

3. What are the limits of isotope analysis — what kinds of questions can it not answer about an ancient individual?