# Activity: Can you determine diet?

## How Diet is Revealed in Bone

The chemical composition of bone reflects some basic staples of diet. Collagen, the protein component of bone, is made up of amino acids whose large molecules contain mainly carbon, nitrogen, oxygen, and hydrogen atoms. The food we eat supplies the atoms that make up amino acids. Because foods from different parts of the world have different carbon signals in the form of isotope ratios, scientists can sometimes identify a person's origins by analyzing the carbon isotopes in his/her bone collagen.

## What are isotopes and how do they become part of our diet and bones?

Atoms having the same number of protons but different numbers of neutrons in their nuclei are called isotopes. Carbon has both a heavy and a light isotope that occurs naturally. Most of the carbon in our environment is the lighter isotope of carbon, Carbon-12 (12C), which has six protons and six neutrons. One percent of the carbon in our world is the heavier isotope, Carbon-13 (13C), with six protons and seven neutrons.

During photosynthesis, all plants take up carbon in the form of $CO_2$ through very small openings in their leaves, called stomata. Some plants use a special enzyme to metabolize carbon into a molecule with four carbon atoms. These are called **C4 plants**. C4 plants are very efficient due to their adaptation to warmer, drier environments. They metabolize almost all the 13C from the $CO_2$ they take up and, therefore, C4 plants retain more of the heavy isotope of carbon, 13C, in their tissues. People who eat these plants or the animals that eat these plants, have more of the heavy isotope of carbon in their bone collagen than those that do not consume C4plants. Many important food crops are C4 plants, including maize (i.e., corn), sorghum, sugarcane, and millet.

Other plants create a molecule with only three carbon atoms from $CO_2$ during photosynthesis. These are called **C3 plants**. C3 plants are not as efficient as C4 plants; more 13C escapes through the stomata in their leaves during photosynthesis. Compared to C4 plants, C3 plants are adapted to cooler, wetter environments. Important C3 food crops include wheat and barley. People who eat these plants or the animals that feed on these plants, have less of the heavy isotope of carbon in their bone collagen than those that consume C4 plants.

# Calculating Carbon Isotope Ratios

Small differences in the isotope ratios are difficult to determine by measuring a material's absolute isotopic composition. Therefore, isotopic concentrations of elements are expressed with respect to an international standard.

$$\delta = \{ [R \text{ sample}/R \text{ standard}] - 1\} \times 1{,}000$$

Let's put this equation into words: the ratio ("R") of 13C to 12C is measured in a sample (such as bone) divided by the ratio of 13C to 12C in the standard (i.e., the constant) which has the highest known ratio of 13C to 12C. The number 1 is subtracted from the ratio of the sample to the standard and this result multiplied by 1,000. The result is the relative differences of the sample's carbon isotope ratio to that of the standard. It is presented as delta values (δ) in parts per thousand, or per mil (0/00). Because most natural substances have less 13C relative to the standard, the results are negative values.

For bones, these are the known values of 13C in parts per thousand ("per mil"):

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|---|---|
| Primarily diet of C4 plants (corn): | -13 to -9 per mil |
| Primarily diet of C3 plants (wheat, barley, rye): | -20 to -17 per mil |
| Combination diet of C3 and C4 plants: | -17 to -14 per mil |

# The Early Colonial Diet

The ratio of the light to heavy isotopes of carbon in bone can change depending on the foods eaten, but it takes many years for bone collagen to be completely replaced in adults. Therefore, the amount of 13C in bone reflects what people ate many years prior to death.

In colonial burials, the amount of 13C in bone collagen tells us not only about diet, but also how long a colonist lived in North America. People living in the Colonies ate more corn then people living in Europe. Corn is a C4 plant, native to the Americas and warmer climates. It has a different chemical signature (i.e., carbon isotope ratio) than wheat or barley, which are both C3 plants and dietary staples in the colder areas of Europe. An English immigrant who died shortly after arriving here would have eaten mainly a European, wheat-based diet. A settler born here would have grown up eating an American, corn-based diet. An English-born colonist who lived in America for years would have eaten a mix of the two.

# Results from the Bones in the Cellar

Isotope analysis of the bones buried in the cellar revealed the following

| | |
|---|---|
| 13C isotope analysis | -19.39 per mil |

# Question:

Do these results suggest that this person's diet throughout individual's life was primarily corn or wheat?

# Resource:

Carbon Isotopes in Photosynthesis, by Marion H. O'Leary, *BioScience*, Vol. 38, No. 5 (May, 1988), pp. 328-336

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