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 (^{12}C), which has six protons and six neutrons. One percent of the carbon in our world is the heavier isotope, Carbon-13 (^{13}C), 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 **C_4 plants**. C_4 plants are very efficient due to their adaptation to warmer, drier environments. They metabolize almost all the ^{13}C from the CO_2 they take up and, therefore, C_4 plants retain more of the heavy isotope of carbon, ^{13}C, 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 C_4 plants. Many important food crops are C_4 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 **C_3 plants**. C_3 plants are not as efficient as C_4 plants; more ^{13}C escapes through the stomata in their leaves during photosynthesis. Compared to C_4 plants, C_3 plants are adapted to cooler, wetter environments. Important C_3 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 C_4 plants.

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 using the following notation:

$$\delta^{13}C = \frac{^{13}C/^{12}C - 1 \times 1000}{^{13}C/^{12}C \text{ (standard)}}$$

Let's put this equation into words: the change in ^{13}C is equal to the relative amounts of ^{13}C and ^{12}C in a sample (such as bone), divided by the fixed proportion of ^{13}C to ^{12}C in the standard (i.e., the constant), the sum of which is multiplied by -1,000. The result is the relative differences of the sample 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 ^{13}C relative to the standard, the results are negative values.

Plants in a Diet	13C isotope value in bone (in parts per mil)
Primarily C_4 plant diet (e.g., corn)	$-13\ ^{0}/_{00}$ to $-9\ ^{0}/_{00}$
Combination diet of C_4 and C_3 plants	$-17\ ^{0}/_{00}$ to $-14\ ^{0}/_{00}$

Primarily C_3 plant diet (e.g., wheat, barely, rye)	-20 $^0/_{00}$ to -17 $^0/_{00}$

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.

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

Analysis	Finding
^{13}C isotope	-19.39 $^0/_{00}$ (parts per mil)

What do you think?

What does the 13C isotope analysis indicate?

- ○ Diet of both corn and wheat, immigrant of several years
- ○ Corn based diet, American-born or long-term immigrant
- ○ Wheat based diet, recent immigrant

Vote

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