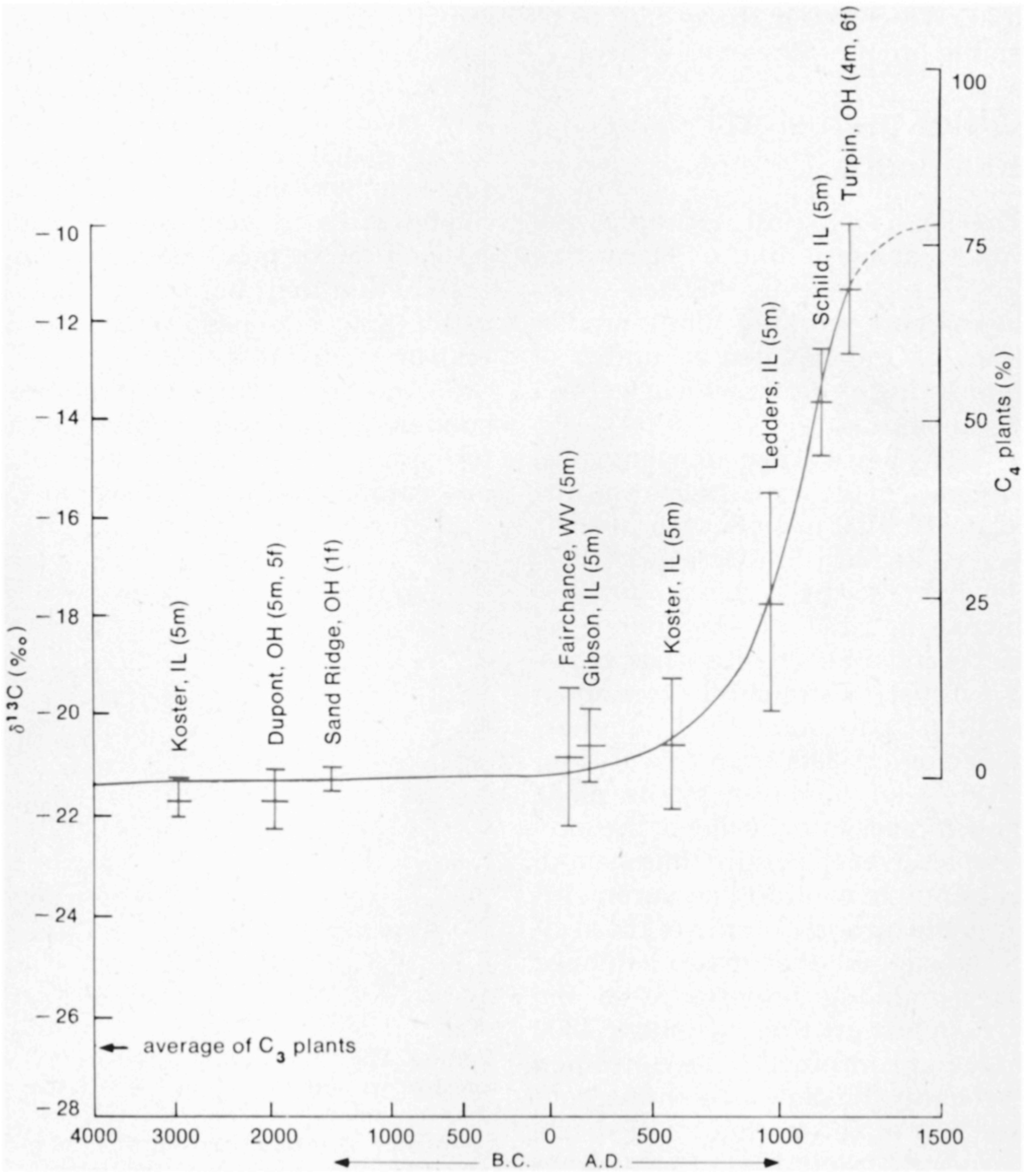
HOW TO USE THIS RESOURCE

Show the graph below to your students along with the caption and background information. The "Interpreting the Graph" and "Discussion Questions" sections provide additional information and suggested questions that you can use to guide a class discussion about the characteristics of the graph and what it shows.



Caption: Carbon isotope ratio data in bone collagen from human skeletons found in Illinois, Ohio, and West Virginia, dated 4,000 B.C. to 1,500 A.D. The number and sex of the individuals found at each location are indicated in parentheses.

BACKGROUND INFORMATION

To study the change in diet as human populations changed lifestyles from hunter-gatherers to agriculturalists, Nikolaas van der Merwe and J. C. Vogel measured carbon isotopes in the collagen tissues of human skeletons from North America dated between 4,000 B.C. and 1,500 A.D. Stable isotopes are different forms of an element with slightly different atomic mass. For example, most carbon (^{12}C) has six protons and six neutrons in the nucleus and an atomic mass of 12, but ^{13}C has six protons and seven neutrons and an atomic mass of 13. Different species of plants contain different ratios of ^{12}C and ^{13}C isotopes depending on the pathway they use for carbon fixation during photosynthesis. Most of the native plants in the Americas are classified as C_3 plants, such as small seeded cereal crops like rice, wheat, barley, and oats, which convert CO_2 to an initial three-carbon compound during photosynthesis. C_4 plants, such as corn and sugarcane, convert CO_2 to an initial four-carbon compound. C_4 plant tissues have a higher ratio of ^{13}C to ^{12}C isotopes than C_3 plants. When animals eat these plants, the carbon isotope ratios, or "isotopic signatures," are stored in their tissues, such as bone collagen. As these tissues are formed, fractionation occurs, which means that the carbon isotope ratios change slightly. For humans who consume C_3 plants, the average fractionation when bone collagen is formed is +5.1‰. Prior to the domestication of corn, C_3 plants were the main food sources for prehistoric humans in North America. The graph above illustrates the change in plant consumption before and after the adoption of domesticated corn as a staple agricultural crop in the American Midwest.

INTERPRETING THE GRAPH

Each data point in the graph shows the average of the relative amounts of ^{13}C in bone collagen from samples of human skeletons over a 5,500-year time period (shown on the *x*-axis). ^{12}C to ^{13}C isotope ratios in samples were measured and compared to the ratio of a universal standard. The difference between the sample and the standard is presented as $\delta^{13}C$, pronounced "delta carbon thirteen," in parts per thousand (‰) (on the left *y*-axis). The right *y*-axis infers the percentage of the diet of these individuals that was made up of C_4 plants. C_3 plants have a ratio of about -26.5‰ (shown by an arrow in the graph), but as bone collagen is formed, that ratio changes by +5.1‰. A human with a diet of only C_3 plants would have a ratio of -21.4‰ and a diet of about 70% C_4 plants would have a ratio of about -12.5‰. The line that goes through the data points is a best-fit curve for the data. Note that the level part of the curve from ~4,000 to 0 B.C. corresponds to 0% C_4 plants in the diets of these Native Americans. The line shows a sharp increase starting at about 200 A.D., indicating a change in diet from predominantly C_3 plants to predominantly C_4 plants.

Teacher Tips:

1. Review the calculation and interpretation of slope with your class.
2. Prompt your students to explain the following:
   - Graph Type: Scatterplot
   - *X*-Axis: Time (years)
   - *Y*-Axis: Left axis: $\delta\ ^{13}C$ measured in parts per thousand, or $^0/_{00}$, in bone collagen; Right axis: Percent (%) C_4 plants in the diet.
   - Error Bars: The original paper does not specify whether these error bars represent standard error or standard deviation. Not knowing the answer to this question opens up discussion

about which statistical methods are appropriate and what the error bars indicate in either case.

DISCUSSION QUESTIONS

- Using evidence from the graph, explain how the diet of North American people changed between 4,000 B.C. and 1,500 A.D.
    - At what point in time did the diet begin to change?
    - Compare the slope of the lines before and after this point in time.
    - How do you think the lifestyle of North Americans changed during this time?
- Genetic and archaeological data from corn and its ancestor teosinte indicate that corn was domesticated around 7000 B.C. in Mexico. However, corn did not become a staple food in the diet of Mexicans until 4000 B.C. and corn did not reach the American southwest until 2000 B.C. What might be some possible explanations for the gap in time before corn is an evident staple in the diet of Midwestern North Americans?
- This shift from a C_3-based diet to a C_4-based diet is thought to have contributed to increases in population, changes in settlement patterns, and development of large-scale societies in early North America. What additional evidence would you need to research to support this claim?

SOURCE

Figure 6 from:
van der Merwe NJ. Carbon Isotopes, Photosynthesis, and Archaeology: Different pathways of photosynthesis cause characteristic changes in carbon isotope ratios that make possible the study of prehistoric human diets. *American Scientist* 1982; 70(6):596-606.

Original data from:
van der Merwe NJ and JC Vogel. 13C content of human collagen as a measure of prehistoric diet in woodland North America. *Nature* 1978; 276:815-6.

AUTHOR

Bob Kuhn, Centennial High School, Roswell, Georgia
Edited by: Marshall Otter, PhD, Marine Biological Laboratory; Laura Bonetta, PhD; Elizabeth Rice, PhD; Laura Helft, PhD; Mark Nielsen, PhD; Aleeza Oshry; Bridget Conneely, HHMI