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Corn Flakes, Rice Krispies or Weetabix:

We can thank our ancestors for the choice

A field of barley, ready for harvesting

Key words
cereals
carbohydrate
archaeology
isotope analysis

Carbohydrates are the major source of energy in the human diet. We consume most of our carbohydrates as large, complex molecules, mainly starch, which our cells can break down into small sugar molecules to release energy. Good sources of starch are cereals – wheat, maize (corn), rice, barley, oats, millet and others – their derived products, including bread, and starchy vegetables – potatoes, yams, cassava and other tubers.

Today, a quick look at the breakfast cereals aisle of your local supermarket will reveal products made from all the cereals listed above. However, none of these crop plants is native to Britain. They were introduced from centres of domestication elsewhere by humans since the development of farming, approximately 10 000 years ago. Some cereals – wheat and barley – were brought to the British Isles by Neolithic farmers over 5000 years ago. Others are much more recent introductions: maize (corn) only arrived in Europe about 500 years ago, from America. Throughout human history and prehistory there have been major episodes in which crop plants have been moved over thousands of kilometres and introduced to new societies, resulting in the diversity of food products available on all five continents today.

Figure 1. *Archaeologists at work at the Botai site, northern Kazakhstan. Samples of soil are carefully removed during the excavation to be sieved for plant fossils and animal bones.*

Figure 2. *Barley reached China between 5000 and 4000 years ago, spreading from the Near East where it was first domesticated around 10 000 years ago. The picture shows some of the oldest barley grains found in north-western China. Some of the charred grains are damaged or broken, but the intact grain in the bottom right of the picture can be clearly recognised as barley by its characteristic shape and surface features.*

Plant journeys

How do we discover when, and along which routes, food plants spread in the past? Scientists work alongside archaeologists to recover information from material excavated from archaeological sites. As well as man-made objects – tools, pots, weapons, clothing, jewellery and the like – archaeologists also recover biological material: human and animal bones, and plant remains (Figure 1). Seeds and other plant debris from farming and cooking activities can be preserved from rotting in one of three ways (see Box: The chemistry of preservation). Archaeobotanists use the characteristic shape and surface features of preserved seeds to identify which crops were grown and used by people in the past (Figure 2).

The chemistry of preservation

Most organic material from the past is degraded by the recycling action of saprotrophic fungi and bacteria in the soil. Only a small fraction is preserved from decay by chance exposure to one of the following environmental conditions.

- Wherever they settle, virtually all human societies create fires for cooking and clearing land. Food plant material that accidentally or intentionally became engulfed in the fire, under the right combustion conditions, became charred – the organic molecules were converted to pure carbon (think of charcoal), which fungi and bacteria cannot digest.
- Very dry environmental conditions preserve plant material by desiccation, because microbial activity is very low where water is unavailable. Fungi and bacteria cannot survive in desert soils: water will be drawn out of their cells by osmosis. In archaeological sites in desert regions, such as Egypt, Sudan, and the Takla Makan desert in northwest China, desiccated seeds are often found.
- Waterlogged environments preserve plant remains from decay by excluding the oxygen that saprotrophic organisms need. The chemistry of waterlogged archaeological sites (examples) is also often acidic. Fungi and bacteria can rarely grow in this harsh low-pH environment.

Silos in Wisconsin, USA, used for storing bulk quantities of cereal grains.

History in our bones

The chemical composition of our bones reflects the foods we have eaten in our lifetimes. Chemists analyse human and animal skeletons from archaeological sites to find out which cereals were the major staples of their consumers' diet (Figure 3).

Figure 3. *Extracting collagen, a protein, from archaeological bone samples. Most of the carbon in bone is stored in collagen. The extracted collagen is then combusted in a mass spectrometer to measure the relative proportions of its stable carbon isotopes.*

This process makes use of the fact that some elements have more than one naturally-occurring stable isotope – different forms of the same element whose atoms have different masses because their nuclei have different numbers of neutrons. Most of the Earth's carbon occurs as the ^{12}C isotope (carbon with an atomic mass of 12), but a small proportion is of the heavier isotope ^{13}C.

When plants fix carbon dioxide from the atmosphere by photosynthesis, they incorporate the ^{12}C and ^{13}C isotopes at different rates. These rates vary according to the biochemical pathway of photosynthesis. Plants that use the C_3 photosynthesis pathway, including the cereals wheat, barley, and rice, incorporate a lower proportion of ^{13}C into their carbohydrate stores than plants that use the C_4 photosynthesis pathway, which include the cereals maize and millet.

When these plants are eaten by animals and humans, this carbon-isotope 'signature' is preserved in their tissues. Archaeological scientists quantify the proportion of the ^{13}C isotope using a mass spectrometer, which measures atomic masses very accurately. Bones with a higher proportion of ^{13}C show that the human or animal ate a diet rich in maize or millet; bones with a lower proportion of ^{13}C come from consumers of wheat, barley or rice.

By determining the age of plant and bone remains from archaeological sites, we can establish limits for the dates when cereals were first grown or used in a particular region. Radiocarbon dating uses an unstable isotope of carbon, ^{14}C, which undergoes radioactive decay at a constant rate after the organism dies. By measuring the amount of ^{14}C that remains in a seed or bone, scientists calculate the age of the sample. Using this method, we know that the earliest wheat (so far) found in China is around 4500 years old. That's around 6000 years later than its first appearance in the archaeological sites of the Near East, from which it probably spread to China.

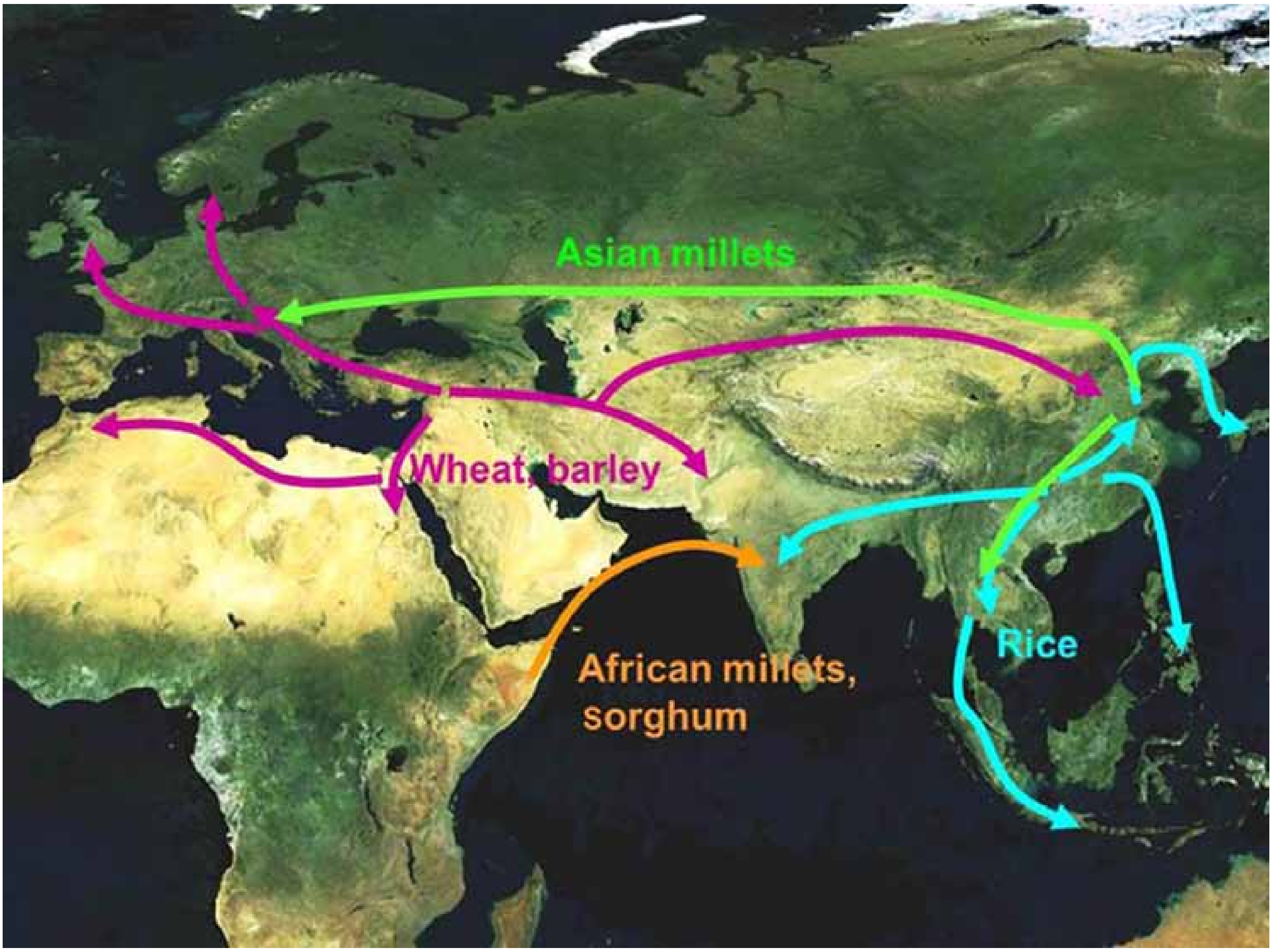

Figure 4. This map shows the routes by which cereals became 'globalised' from their different centres of origin in the period 5000 – 4000 years ago. Evidence from genetic work has been combined with data from archaeological plant remains to put together the map.

DNA evidence

The crop plants grown today also hold clues to the past in their DNA. Genetic variation slowly accumulates in crops over thousands of years as a result of mutations in their DNA, resulting in different varieties that are grown in different parts of the world. Varieties that diverged from one another (shared a common ancestor) many thousands of years ago have more genetic differences between them than varieties that diverged from one another recently. In the same way, we share more genes in common with people close to us on our family tree than we do with the population in general (to whom we are still related, but very distantly).

Geneticists analyse the DNA of cereal varieties to identify alleles (different forms of a gene that have arisen by mutation) of one or more genes. Sometimes these genes have a known role in the plant (e.g. a gene that controls seed colour), but often they have unknown function or are regions of DNA with no function at all. Regardless of its function, geneticists can use the DNA to group related varieties into 'families', according to which varieties have most alleles in common. By looking at the geographic distribution of these families today, we can infer where crops spread from in the past (Figure 4).

An example from human genetics makes this easier to understand. Black Americans share many alleles with people in Africa, from where they were originally brought as slaves in the last 500 years. White Americans mostly originate from European settler populations, and share many alleles with Europeans alive today. Genetic analysis of barley shows that there were at least two waves of introduction to Europe of this crop from its Near Eastern origins.

The diversification of food sources used by people in different parts of the world is an important topic for anthropologists, archaeologists, health policy professionals, and economists. The fundamental advances in knowledge in this area rely on the skills of biologists and chemists, who piece together the past from archaeological fossils and the genetic diversity around us.

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