ANCIENT BIOMOLECULES INITIATIVE

Molecular Signatures from the Past

Ancient biomolecules tell the tale

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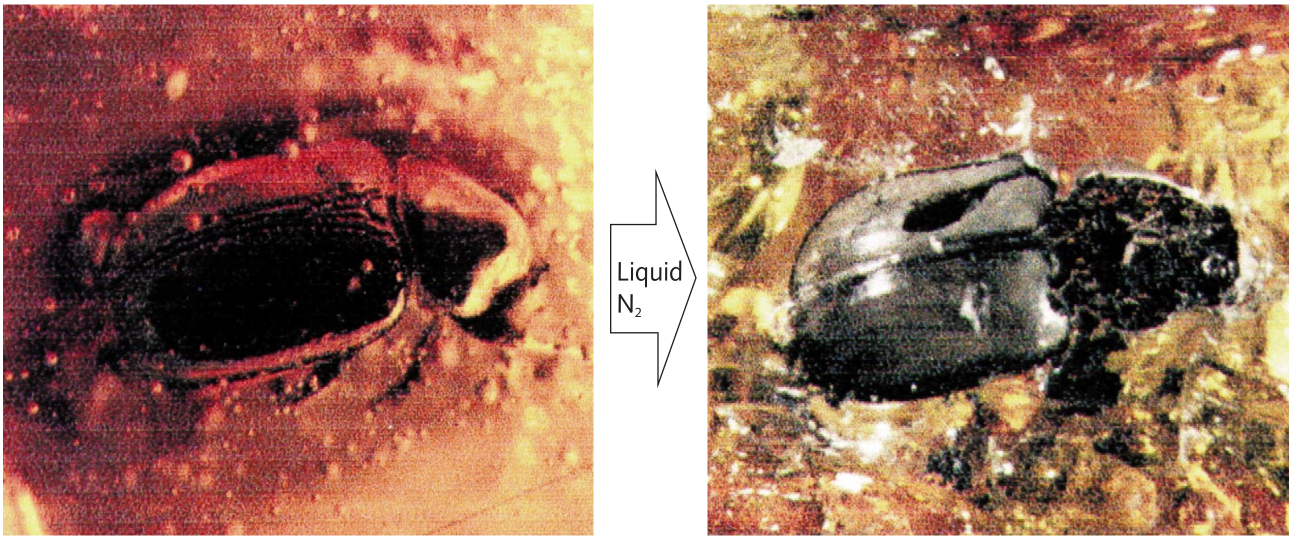

Photo courtesy of Biogeochemistry Research Centre, Dept of Geology, University of Bristol.

A chrysomelid beetle in Dominican amber (25 to 30 million years old) before and after exposure by cracking the amber using liquid nitrogen. The removal of the overlying amber has expposed the wing cases. The cuticle covering the front part of the beetle has come off, exposing the internal tissue. The newly-exposed beetle looks as if it died yesterday but analysis reveals extensive decomposition of the biomolecules originally present.

Where do dinosaur bones, insects in amber and molecular biologists co-exist? In Jurassic Park of course - but also in the Ancient Biomolecules Initiative (ABI), a £1.9 million research programme funded by the Natural Environment Research Council. ABI was set up to find out more about how ancient biological molecules are preserved over thousands to millions of years, and what they can tell us about the past.

Ancient biomolecule analysis has now become a reproducible science, and UK is in the forefront of that science. Molecular signatures from the past are providing fascinating insights into early human society, the migrations of ancient people and the origins and practices of early agriculture. The organic fingerprints also provide pieces in the vast jigsaw of past climate, and help in pinpointing potential oil reservoirs.

We have all observed that plants and animals decay rather quickly when they die - just think of your compost heap. Bacteria, fungi, maggots and scavengers make short work of most dead biological material. But some of it can survive for hundreds or even millions of years, for instance as fossil fuels. How is this possible?

Nature's compost heap

Nature's recycling is almost perfect, but not quite. Some of our best known archaeological sites, such as Viking York and the *Mary Rose* show wood and other tissues surviving centuries. Ancient wooden trackways beneath the Somerset peat levels have persisted for thousands of years. Deeper sediments elsewhere can reveal seeds, leaves and insects that look relatively intact.

Each year about one part in a thousand of the world's biomass slips out of the cycle to accumulate in the earth's crust. Not a very large part, but in a century those leftovers have grown to one part in ten. In a few millennia they have formed into great swathes of peat in areas like the UK moorlands and thick layers of organic-rich muds in some regions of the sea floor. Over geological time, the amount of combined carbon cycling through living things at the earth's surface is dwarfed by the vast reservoirs of carbon in the biomolecular debris below ground.

What is a biomolecule?

Biomolecules are molecules made by living organisms. They can be small, like cholesterol or an amino acid, or very large, like proteins such as keratin (hair) or collagen (the organic part of bones) and DNA. Organisms use the small biomolecules as "building blocks" to make the larger ones.

The vast assemblage of biomolecules making up a living organism can provide a molecular signature of past life, as long as some molecules survive decay, either intact or so little modified that we can still recognise them.

ABI scientists set out to discover what happens to biological molecules over time - not just DNA from insects in amber, but other molecules such as proteins and fats in bones and the hard outer casings of insects and plants.

Novel techniques

ABI researchers have been using novel techniques to probe survival at the molecular level. Some biomolecules allow past climates to be studied: changing temperatures are charted by variations in certain molecular ratios. Others allow ancient foods to be identified, even when the foodstuff has been long since cooked and eaten. Some molecules are lodged in our distant ancestor's bones, storing details of diet, health and lineage. Perhaps the most remarkable of these is the blueprint of life, DNA, which can answer questions about the evolution of species, human migrations and the origins and practices of early agriculture.

The Ancient Biomolecules Initiative is a five-year programme to understand the fate of biological molecules in archaeological and fossil materials, and to explore the applications of this new knowledge. The Initiative is funded by the Natural Environment Research Council.

Natural Environment Research Council

Ancient biomolecules tell the tale: what has ABI found out?

Photo courtesy of Dr B Sykes.

An early European farmer? A human skeleton, probably male, being excavated at an LBK site in Enzingen, Baden-Wurtenberg, Germany. It is from the middle of the LBK period and is about 5000 years old. Samples for DNA analysis were collected using modern forensic procedures to avoid contamination. The linienbandkeramik (LBK) culture, characterised by its pottery, was widespread in Europe.

Ancient DNA

ABI scientists have been refining and building on methods which could unlock the vast stock of genetic information archived in museums or preserved by chance. The researchers have worked at the extreme edge of the polymerase chain reaction and other DNA techniques (sheet 04).

Finding enough intact pieces of DNA of the sequence being sought is a major challenge. Problems of contamination abound, since contaminants will far outweigh the minuscule amounts of ancient DNA. Nevertheless, it is apparent that fragments of a few hundred base pairs are regularly retrievable from plants, bones, and other remains of up to a few tens of thousands of years old, but only where preservation has been good.

We continue to need independent replication of such results if we are really to establish the ancient DNA field as a normal part of archaeological and palaeontological research. Replication has not proven attainable for any of the specimens that are millions of years old, not even the DNA from amber (sheet 11) which some researchers had expected to be an optimal medium for preservation.

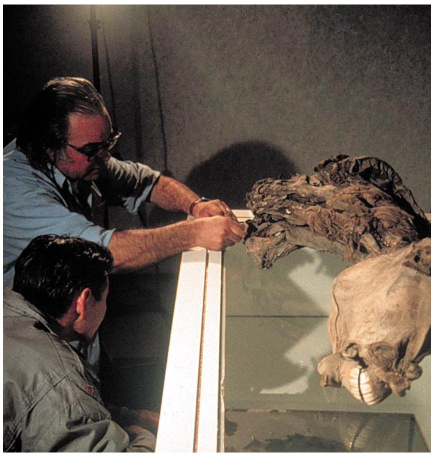

Photo courtesy of Dr A Lister.

Sampling an extremely well-preserved horse carcass from Yakutia, Siberia, while on display at Dinard, France in 1994. The specimen, dated to 26,000 years ago had naturally freeze-dried by a process akin to mummification. These animals were probably similar to the European animals represented in cave art which must have roamed across the broad grassy plains of Eurasia during the late Ice Age.

ABI researchers have for the first time begun to discern the limits in time and conditions in which ancient DNA can be expected to survive, limits which are only partly consistent with studies of the decay of modern DNA in the laboratory. The timescale is measured in tens of thousands of years (sheets 03-09) and preservation is favoured by both cold and dry conditions. ABI research has provided new insights both into the spread of early farming communities around the world (sheets 03, 09 and 10) and in the lineage of crops and livestock they carried with them (sheets 06-10).

Proteins and other biomolecules

DNA may be the most remarkable molecular survivor, but it is by no means the most durable. Proteins may last longer (sheets 18 and 19) and components of woody tissue, plant and insect coats, fats, oils and waxes may persist into geological time. A new generation of improved techniques allows the molecules to be studied in such detail that they can yield evidence comparable in precision to DNA (sheets 13-17). ABI scientists have produced improved methods for extracting protein from ancient bones without destroying much of the useful information it contains (sheet 19).

There is a great deal more to the accumulation of organic matter than fossils. Sediments on lake bottoms and sea beds are far richer in biomarker molecules than we might suspect. We are now beginning to understand why they survive at all, and what information is locked up within them (sheets 15-17). Life doesn't end as the sediments around these biomolecules harden and consolidate. Some bacteria slowly consume these molecules in the most extraordinary circumstances, a kilometre deep in the ocean floor muds, and possibly even in the heart of rock salt crystals. If so, these crystals may harbour some of the most ancient life on the planet (sheet 12).

Applications of the research

The programme's applications are many and varied. They include new ways of understanding the archaeology of agriculture and human migrations over the last 15,000 years. ABI methods can assist in the management of archaeological sites, especially wet anoxic sites where the preservation of archaeological materials can be excellent, but highly sensitive to minor fluctuations in their chemical environment.

New scientific data can assist in interpreting our archaeological heritage and thus boost tourism. ABI science can be used in forensic science, agriculture and veterinary science, as well as by the oil and gas industry.

The Future

We have barely scratched the surface of this exciting area of science. Just what features of the environment immediately around a molecule determine whether or not it persists over time? Major challenges remain. We need to know exactly how different molecules are preserved and the nature of their long-term fate. The key to progress lies in precise and detailed knowledge of the biomolecular structures and the changes they undergo in leaving the living world and passing into the archaeological and palaeontological record. This is an interdisciplinary area which has great potential for acquiring fundamental new knowledge.

Professor Martin K Jones (ABI Chairman),
Department of Archaeology,
University of Cambridge,
Cambridge CB2 3DZ,
tel: 01223 333529, fax: 01223 333503.

Professor Geoffrey Eglinton FRS (ABI Manager),
Biogeochemistry Centre,
Department of Geology,
University of Bristol,
Bristol BS8 1RJ,
tel: 0117 928 8858/ 0117 968 3833,
fax: 0117 925 3385/ 0117 962 6065.
email: geoff.eglinton@bristol.ac.uk