Remains of Denmark's royal saint

Thanks to a unique method of radiocarbon dating, textiles in an 11th century crypt reveal the thread of events long past

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Murder of Canute the Holy by Christian Albrecht von Benzon, 1843

Science often ties up loose ends that historical records cannot bring together. Poul Grinder-Hansen, Ulla Kjær1 Morten Ryhl-Svendsen, Maria Perla Colombini, Ilaria Degano, Jacopo La Nasa , Francesca Sabatini, Johannes van der Plicht and Kaare Lund Rasmussen, of National Museum of Denmark and Royal Danish Academy of Fine Arts, Copenhagen, Università Di Pisa, Italy, Center for Isotope Research, Groningen and Leiden University, The Netherlands, and University of Southern Denmark, Odense, describe in the journal, *Heritage Science*, their work on the contents of an 11th century Danish crypt, which resolves a question of their antiquity.

The crypt in question is in St Canute's Cathedral in Denmark's Odense and it houses two 1.5 metre-long wooden coffins, or the shrines, with the remains of the Danish king, Canute the Holy (approximately 1040-1086) and his younger half-brother Benedikt. The coffins, over centuries, had been stripped of their original ornamentation and there was need to keep them hidden. When they were finally discovered, in 1694, they were found stored upright, with the bones, and the cloth that had covered them, in a heap at the bottom.

The paper in *Heritage Science* recounts the history of the Danish royal saint. King Canute IV, or Canute the Holy or St Canute, one of the many sons of King Svend Estridsen, who reigned in Denmark around 1047-1074. When he died, five sons, one after another, became king, and King Canute was the second in the line. "His ideal was that of a strong royal power and his attempts to realise it in cooperation with the Church made him many enemies," the paper says. The result was that in July 1086, King Canute and his brother were killed, with 17 others. As the king had taken refuge in St Alban's Church, in Odense, when he was hunted down, he was killed on holy ground, a fact that helped remaining members of the royal family, in 1101, to have King Canute canonised as Saint Canute.

As the remains of a saint, King Canute's bones were moved to a stone coffin below a new church being built in his honour, and then to an ornamented container in the newly built St Canute's Church. The paper cites records that say, "The royal bones were wrapped in silk and placed in a marvellous shrine forged of yellow shining metal and decorated by precious blue and yellow stones." There were other references, from time to time, that the shrine was venerated, placed on an altar and displayed, and taken out in procession in the town of Odense, in connection with the saint's day of martyrdom in July.

There are other records, the paper says, of demands from rebel leaders and from the king, for taxes and levies, and a mention, in 1536, of the monastery of St Canute having drawn on the silver from a shrine in the church to meet the dues. There are further references, possibly to the same crypt, when the church was rebuilt, in 1582, and in writings, and visits by foreign Catholics, including one in 1622. And then, in 1694, when the shrines were found again in a recess in the wall, there is a description of the state of the shrines and their contents.

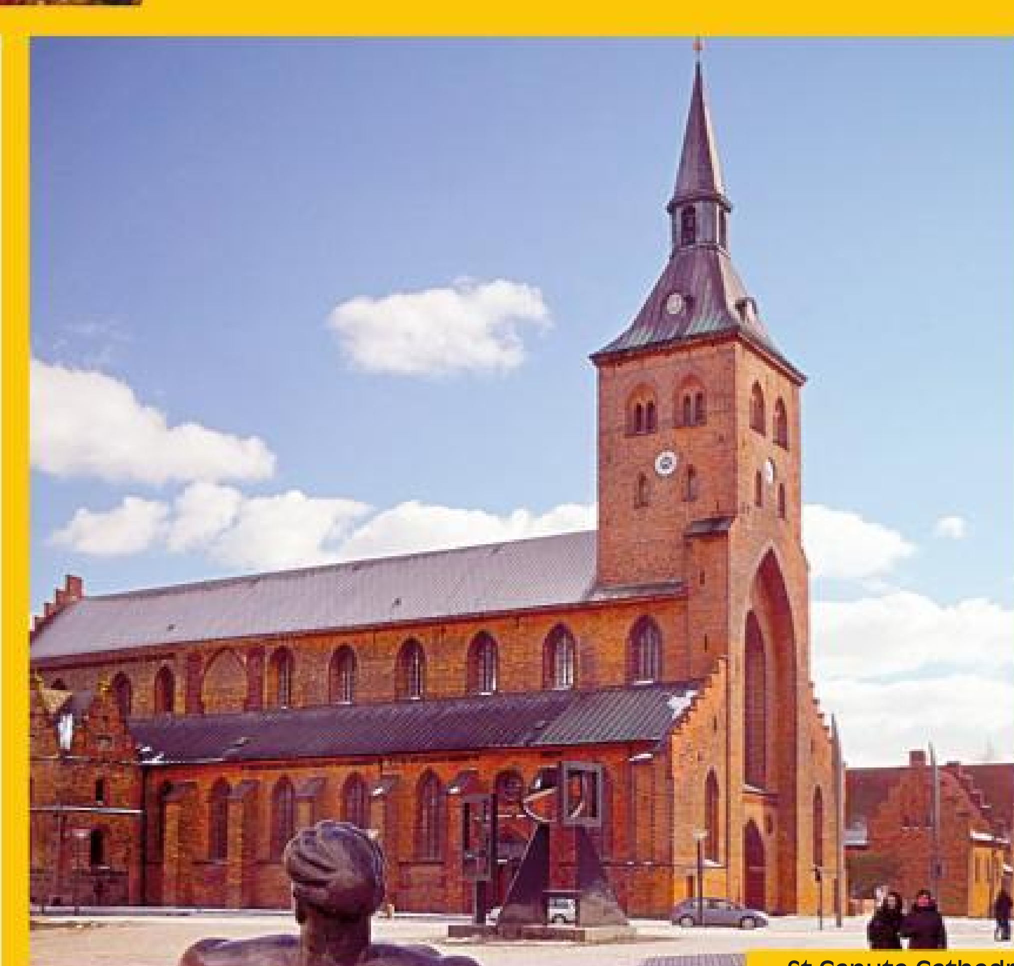
It was in 1833, the paper says, that the shrines were fitted with new glass lids and properly displayed. More importantly, the paper says, the textiles, which were rich and rare silks, were taken out and moved to the National Museum in Copenhagen. Again, in 1875, the shrines, bones and cloth were restored and the cloth, which was considered fragile, was described in detail. And in modern times, recognising the effects of humidity and exposure, the relics are preserved in specially designed showcases.

As a result of the "chaotic" movement and handling of the relics, even before 1833, there has been some uncertainty about their identity and antiquity. There are suggestions that the bones are of a nephew of King Canute and that the textiles were added later. Whether the dates assigned to the bones and the wood in the shrine are authentic, are questions to be answered, the paper says. And then, of the environment within the glass cases – how well the contents are conserved and the possibility of contaminants, which may have even affected the radiocarbon dating.

The current investigation used sensitive chemical analyses and radiocarbon dating,using the method of Accelerator Mass Spectroscopy. Radiocarbon dating depends on the fact that the carbon atoms consist of different forms, for the most part in a form called ^{12}C, or atoms that have 12 particles in the nucleus, and for a miniscule part, in a form called ^{14}C, where the nucleus has 14 particles. Now, the ^{14}C part is radioactive, which is to say, it decays, and its presence in a sample would reduce with time. The ratio of the two kinds of carbon, however, have stabilised, so that processes that give rise to ^{14}C just compensate the rate of decay, and the ^{14}C component of carbon is constant.

This is true so long as the carbon is part of nature and the part that decays is being replenished. If the carbon is fixed in a piece of cloth, or in bones when the body dies, or wood, when a tree is cut, however, the ^{14}C content reduces with time. As ^{14}C is radioactive, we can measure the activity and assess how much ^{14}C there is left, and hence the age of the sample.

This is the conventional method of radiocarbon dating, which is useful to date the wood in ancient ruins, remains of animals, organic matter in artefacts or isolated geological samples. The trouble is that the method needs a reasonable quantity – 10 grams of wood or charcoal and 100 grams of bones and sediments – of the material to be dated. In AMS, on the other hand, the level of ^{14}C is detected directly. The carbon in a tiny sample – as low as 20 milligrams – is extracted and irradiated with cesium ions. This generates carbon ions, or negatively charged carbon atoms, which are accelerated by an electric field. When a beam of speeding carbon ions is deflected by a magnetic field, the deflection depends on the mass, and the ^{14}C ions separate from the ^{12}C (and ^{13}C) ions and the dating can be more precise.



St Canute Cathedral

AMS established the dates of the textiles as 1045-1155 – a wide range, but it shows that all nine pieces of cloth were manufactured close to the date, 1100, of enshrinement. Radiocarbon dating of the bones again match the year, 1086, of the death of King Canute and his half-brother. Analysis of the wood similarly shows that the timber was harvested around 1100.

As for protection of the relics, through the action taken in 1833 or the current methods, analyses of the air surrounding the relics, as well as the exchange with the environment indicates that it can be improved. That the relics are in sealed containers saves them from the environment, but the decay of the oak wood releases substances that could affect all the objects being displayed.

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PERFORMING SPECIFIC FUNCTIONS

Cell specialisation demonstrates the unity and diversity of biology

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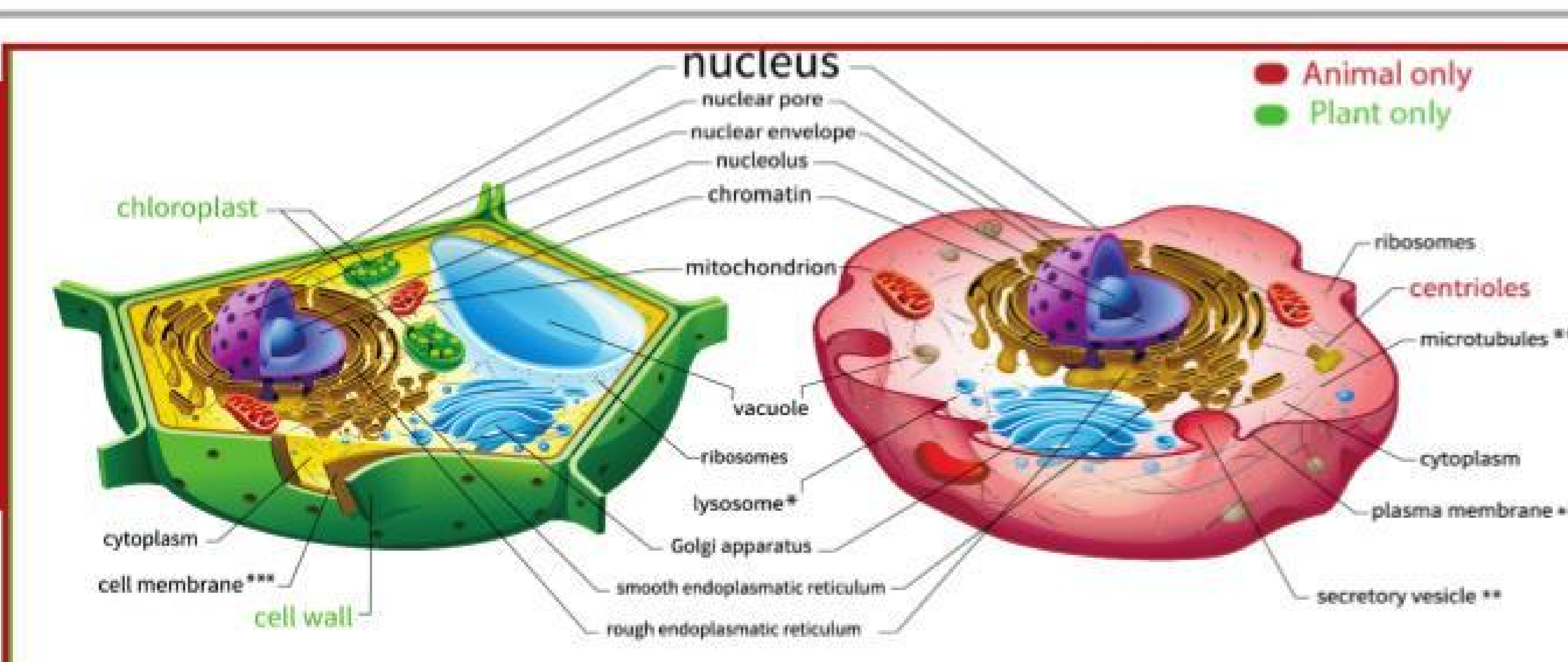

* Plants may have lytic vacuoles, which act like lysosomes in animal cells.
** Although they're not labelled here, plant cells have microtubules and secretory vesicles, too.
*** Cell membrane and plasma membrane are just different names for the same structure.

In terms of structure and function, cells are characterised by both unity and diversity. By unity and diversity, one simply means that all cells resemble one another in fundamental ways, and yet differ from one another in important ways. A few aspects of structure and function are common to most cell types, and these are the features of cells that are of the greatest general interest. That virtually all cells oxidise sugar molecules for energy, transport ions across membranes, transcribe DNA into RNA, and undergo division to generate daughter cells.

Much the same is true in terms of structural features. All cells are surrounded by a selectively permeable membrane, all have ribosomes for the purpose of protein synthesis, and most contain double-stranded DNA as their genetic information. The fundamental aspects of cellular organisation and function are common to most, if not all, cells.

But sometimes, understanding cellular biology is enhanced by considering not just the unity but also the diversity of cells – not just features common to most cells, but also features that are especially prominent in a particular cell type. For example, to understand how the process of protein secretion works, it would obviously be an advantage to consider a cell that is highly specialised for that function. Cells from the human pancreas would be a good choice, for example, because they secrete large amounts of digestive enzymes, such as amylase and trypsin.

Similarly, to study functions known to occur in mitochondria, it would clearly be an advantage to select a cell type that is highly specialised in the energy-releasing processes that occur in the mitochondrion, since such a cell would probably have a lot of well-developed, highly active mitochondria. It was for this very reason, in fact, that Hans Krebs chose the flight muscle of the pigeon as the tissue with which to carry out the now-classic studies on the cyclic pathway of oxidative reactions that we know as the tricarboxylic acid, or Krebs cycle.

Whenever one exploits the specialised functions of specific cell types, they are acknowledging the diversity of cell structure and function that arises primarily because of cellular specialisation. In general, the single cell of unicellular organisms such as eubacteria, archaea, protozoa, and some algae must be capable of carrying out any or all the functions necessary for survival, growth, and reproduction and cannot afford to overemphasise any single function at the expense of others.

Multicellular organisms, on the other hand, are characterised by a division of labour among tissues and organs that not only allows for, but actually depends on, specialisation of structure and function. Whole groups of cells become highly specialised for a particular task, which then becomes their specific role in the overall economy of the organism.

All cells carry out many of the same basic functions and have some of the same basic structural features. However, the cells of eukaryotic organisms are far more complicated structurally than prokaryotic cells, primarily because of the organelles and other intracellular structures that eukaryotes use to compartmentalise various functions. The structural complexity of eukaryotic cells is illustrated by the typical animal and plant cells.

In reality, of course, there is no such thing as a truly "typical" cell; all eukaryotic cells have features that distinguish them from the generalised cells. Nonetheless, most eukaryotic cells are sufficiently similar to warrant a general overview of their structural features.

A typical eukaryotic cell has in essence at least four major structural features – a plasma (or cell) membrane to define its boundary and retain its contents, a nucleus to house the DNA that directs cellular activities, membrane-bound organelles in which various cellular functions are localised, and the cytosol interlaced by a cytoskeleton of tubules and filaments. In addition, plant cells have a rigid cell wall external to the plasma membrane. Animal cells do not have a wall but are usually surrounded by an extracellular matrix, which consists primarily of collagen and a special class of proteins called proteoglycans.

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PLUS POINTS

Beirut blast analysis

The explosion in the Port of Beirut was one of the biggest non-nuclear blasts in history – releasing enough energy in a matter of milliseconds to power more than 100 homes for a year – according to a new assessment of the disaster by engineers from the University of Sheffield in the UK.

Researchers behind the study, from the University's Blast and Impact Engineering Research Group, hope that the new assessment can be used to provide policymakers and the public with more accurate information on the blast, as well as to help first responders prepare for future disasters and save lives.

After analysing videos of the explosion posted on social media, the team of researchers has been able to estimate the power of the blast by tracking how the explosion's shockwave spread through the city. The new assessment, which has been published in the journal *Shock Waves*, found that the size of the explosion was the equivalent of between 500-1,100 tonnes of TNT --- around 1/20th of the size of the atomic bomb that was used on Hiroshima on 6 August 1945 and is one of the largest non-nuclear explosions ever recorded. The explosion also released the equivalent of around 1GWh of energy. This is equal to the hourly energy generated by three million solar panels or 400 wind turbines.

Sam Rigby, senior lecturer in blast and impact engineering at the University of Sheffield, said, "The reason why we decided to analyse the explosion is because as engineers it's our jobs to use the skills and resources we have at our disposal to solve problems and ultimately help people. By understanding more about the power of large-scale accidental explosions like the one that occurred in Beirut, we can develop more accurate predictions of how different buildings will be affected, and the types of injuries there are likely to be at different distances from the blast."

Using by-products

Researchers at the Indian Institute of Technology-Madras are working with Massachusetts Institute of Technology, US, to develop a novel framework for high volume usage of by-products in structural materials. Industrial by-products are generated in huge quantities across the world and are now going into waste. This will be a major step forward towards a sustainable future.

The main outcome expected from this research is achieving a paradigm shift in material selection criteria for exploiting the usefulness of agricultural and industrial by-products. By successfully utilising vast amounts of otherwise-undesired materials, the next generation of sustainable and durable building materials could be designed, like the prototype *in the photo* above. These novel building materials will be attractive due to lower cost and environmental impact than existing materials.

This project is being led by Piyush Chaunsali and Ravindra Gettu, department of civil engineering, IIT-Madras, with Elsa A Olivetti, Atlantic Richfield associate professor of energy studies, MIT. The research project was taken up under the Scheme for Promotion of Academic and Research Collaboration, Ministry of Education, Government of India.

The problem being addressed by the researchers is that by-products such as biomass ash, coal ash, red mud, and copper slag, among others, are generated in large volumes and remain mostly underutilised due to their complex physico-chemical characteristics. The project aims to address growing challenges regarding the beneficial utilisation of voluminous industrial by-products generated in India. Infrastructure construction offers potential sinks for these source materials due to the enormous volume usages, in applications such as roads, buildings and bridges, among others.

This research project combines the principles of materials chemistry, structural engineering, and life-cycle analysis to develop load bearing, durable, sustainable, and economically viable cementitious binders based on industrial by-products in India.