News in focus

STEPHANE DE SAKUTIN/AFP/GETTY

The devastating fire at Notre-Dame de Paris last April destroyed the cathedral's roof and spire.

THE HUGE SCIENTIFIC EFFORT TO STUDY NOTRE-DAME'S ASHES

Last year's fire at Paris's beloved cathedral shocked the world. Now, researchers are making use of the unprecedented opportunity to study its materials.

By Philip Ball

The fire that destroyed large sections of the iconic cathedral Notre-Dame de Paris last April was a national tragedy. Now, months on, scientists with the French national research organization CNRS are embarking on a multi-million-euro effort to study the 850-year-old building and its materials with the goal of illuminating how it was constructed. With unprecedented access to the cathedral's fabric — including timber, metalwork and the building's foundations — in the wake of the fire, scientists also hope that their work will arm them with information to help the restoration.

The research could "write a new page in the history of Notre-Dame, because there are currently many grey areas," says Yves Gallet, a historian of Gothic architecture at the University of Bordeaux-Montaigne, who is in charge of a 30-strong research team investigating the masonry.

Construction of the cathedral, considered one of the finest examples of the French Gothic style, began in the twelfth century. The structure was modified in the Middle Ages and extensively restored in the nineteenth century. But it has been the subject of surprisingly little scientific research compared with other Gothic monuments in France and elsewhere, says Martine Regert, a biomolecular archaeologist at the CNRS's CEPAM centre for the study of historical cultures and environments in Nice, who is one of the project's leaders. Many questions remain about the structure, such as which sections are medieval and whether architect Eugène Viollet-Le-Duc, who supervised the nineteenth-century renovation, reused some of the older materials, says Regert.

The fire on 15 April, possibly caused by an electrical fault, destroyed the cathedral's roof and spire, and caused part of its vaulted

ceiling to collapse. The walls still stand, and the building will eventually be restored – although this is likely to take longer than the ambitious five years initially forecast, and is set to cost hundreds of millions of euros.

But, until then, the interior of the building holds piles of debris: fallen stonework, burnt timbers and damaged metal artefacts, all now available for scientific study. The absence of tourists might also make it possible to use radar to probe the foundations, which have been little investigated before. Even some parts of the structure that were largely undamaged are now more accessible for inspection, says metals specialist Philippe Dillmann of the CNRS Laboratory for Archaeomaterials and Alteration Forecasting in Gif-sur-Yvette, who is coordinating the project with Regert.

Architectural investigations

The CNRS project will focus on seven topics: masonry, wood, metalwork, glass, acoustics, digital data collection and anthropology. In all, the effort will involve more than 100 researchers in 25 laboratories and will last for 6 years.

Gallet's team will study Notre-Dame's stones to identify the quarries that supplied them and "reconstruct the supply networks and the economy of the site". Studying the mortar used to bind the stones together could reveal how different compositions were used for the various structural elements – vaulting, walls and flying buttresses. A better knowledge of the historical materials could inform choices made in restoration, says Gallet.

The team will also analyse weaknesses in the remaining structure caused by the high temperatures of the fire, and by the fall of masonry and the water used to extinguish the flames. A radar study will determine how solid the foundations are before restorers erect scaffolding to allow them to dismantle the unstable remnants of the nineteenth-century spire.

Meanwhile, a team of about 50 will focus on Notre-Dame's famous woodwork – especially the timbers in the roof space above the vaults, dubbed the forest – which has either burnt away or lies charred in the nave. These blackened remains could be tremendously valuable to researchers.

"The burnt structure constitutes a gigantic laboratory for archaeology," says dendrologist Alexa Dufraisse of the National Museum of Natural History in Paris, who will lead the multidisciplinary wood team.

"Wood is an extraordinary source of information," says Regert. Initial observations have confirmed that the 'forest' is made of oak, but studies will pinpoint the exact species used and give researchers clues about the techniques and tools of medieval timber construction.

Tree-ring dating of timber beams could reveal the year and location in which the trees were felled, filling in gaps in knowledge about the sequence of construction. "Each tree records within its tissues the environment in which it has grown," says Dufraisse. This kind of study "could never have been conducted without the destruction of the structure by fire", she says.

In particular, says Regert, the wood is a climate archive. "Isotopic analyses of oxygen and carbon in the rings make it possible to determine the temperature and rainfall over time," she says. The trees used in Notre-Dame grew between the eleventh and thirteenth centuries, during a warm period known as the medieval climate optimum, offering a reference period for natural climate warming to compare with anthropogenic warming today.

"The burnt structure constitutes a gigantic laboratory for archaeology."

Access all areas?

Collecting and excavating the materials for analysis is challenging. There are three main piles of debris – in the nave, the north transept and the crossing between the two – as well as material still on top of the remaining vaults. But these are currently off-limits to people for safety reasons, Dillmann says – so robots and drones must do all the collecting. Some of this material might ultimately be reused in restoration.

The collection and analysis will need to be documented precisely and thoroughly. Livio de Luca, a specialist in digital mapping of architecture at the CNRS's Mixed Research Unit in Marseille will lead a team dedicated to creating a "digital ecosystem" that summarizes both the scientific research and the current and previous states of the cathedral, drawing on the work of scientists, historians, archaeologists, engineers and curators – and perhaps even on old tourist photos of the structure.

"It will be like a 'digital twin' of the cathedral, able to evolve as the studies progress," de Luca says. It will include online models for 3D visualization of the building and its attributes, created from billions of data points, with the history and evolution of the structure superimposed on the spatial map.

As well as deepening researchers' understanding of this monumental building, Regert hopes that the scientific studies will be useful when its ravaged vaults rise again. The results, she says, might "illuminate the choices that society will have to make for the restoration".

WHAT CRISPR-BABY PRISON SENTENCES MEAN FOR RESEARCH

Chinese court sends strong signal by punishing He Jiankui and two colleagues.

By David Cyranoski

A Chinese court has sentenced He Jiankui, the biophysicist who announced that he had created the world's first gene-edited babies, to three years in prison for "illegal medical practice", and handed down shorter sentences to two colleagues who assisted him. The punishments put to rest speculation over whether the Chinese government would bring criminal charges for an act that shocked the world, and they are likely to deter others from similar behaviour, say Chinese scientists.

There has been much speculation about whether other scientists would follow in He's footsteps, especially given the relative ease of using the most popular gene-editing tool, CRISPR–Cas9. But the punishments are "definitely a deterrent to similar misconduct in China", says Wei Wensheng, a gene-editing researcher at Peking University in Beijing.

On 30 December, a court in Shenzhen announced that He and two colleagues had flouted regulations and research ethics by altering genes in human embryos that were then implanted into two women, according to Xinhua News Agency. One woman gave birth to twin girls in late 2018; the court said a third baby has been born but did not say when, a revelation that fits with He's claim in November 2018 that a second woman had been implanted with a gene-edited embryo.