

Revealing the nanostructure of wood could help raise height limits for wooden skyscrapers

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There is increasing interest around the world in using timber as a lighter, more sustainable construction alternative to steel and concrete. While

wood has been used in buildings for millennia, its mechanical properties have not, as yet, measured up to all modern building standards for major superstructures. This is due partly to a limited understanding of the precise structure of wood cells.

The research, published today in the journal *Frontiers in Plant Science*, has also identified the plant *Arabidopsis thaliana* as a suitable model to help direct future forestry breeding programmes.

Dr. Jan Lyczakowski, the paper's first author from Cambridge University's Department of Biochemistry, who is now based at Jagiellonian University, said, "It is the molecular architecture of wood that determines its strength, but until now we didn't know the precise molecular arrangement of cylindrical structures called microfibrils in the wood cells. This new technique has allowed us to see the composition of the microfibrils, and how the molecular arrangement differs between plants, and it helps us understand how this might impact on wood density and strength."

The main building blocks of wood are the secondary walls around each wood cell, which are made of a matrix of large polymers called cellulose and hemicellulose, and impregnated with lignin. Trees such as the giant sequoia can only achieve their vast heights because of these secondary cell walls, which provide a rigid structure around the cells in their trunks.

The team from Cambridge University's Department of Biochemistry and Sainsbury Laboratory (SLCU) adapted low-temperature scanning [electron microscopy](#) (cryo-SEM) to image the nanoscale architecture of tree cell walls in their living state. This revealed the microscopic detail of the secondary cell wall microfibrils, which are 1000 times narrower than the width of a human hair.

To compare different trees, they collected wood samples from spruce,

gingko and poplar trees in the Cambridge University Botanic Garden. Samples were snap-frozen down to minus 200°C to preserve the cells in their live hydrated state, then coated in an ultra-thin platinum film three nanometres thick to give good visible contrast under the microscope.

"Our cryo-SEM is a significant advance over previously used techniques and has allowed us to image hydrated wood cells for the first time", said Dr. Raymond Wightman, Microscopy Core Facility Manager at SLCU. "It has revealed that there are microfibril structures with a diameter exceeding 10 nanometres in both softwood and hardwood species, and confirmed they are common across all trees studied."

Cryo-SEM is a powerful imaging tool to help understand various processes underlying plant development. Previous microscopy of wood was limited to dehydrated wood samples that had to be either dried, heated or chemically processed before they could be imaged.

The team also imaged the secondary cell walls of *Arabidopsis thaliana*, an annual plant widely used as the standard reference plant for genetics and molecular biology research. They found that it too had prominent microfibril structures. This discovery means that *Arabidopsis* could be used as a model for further research on wood architecture. Using a collection of *Arabidopsis* plants with different mutations relating to their secondary cell wall formation, the team was able to study the involvement of specific molecules in the formation and maturation of microfibrils.

Dr. Matthieu Bourdon, a research associate at SLCU, said, "The variants of *Arabidopsis* allowed us to determine the contribution of different molecules—like cellulose, xylan and lignin—to microfibril formation and maturation. As a result, we are now developing a better understanding of the processes involved in assembling cell walls."

The wealth of Arabidopsis genetic resources offers a valuable tool to further study the complex deposition of secondary cell wall polymers, and their role in defining the fine structure of cell walls and how these mature into wood.

"Visualising the molecular architecture of wood allows us to investigate how changing the arrangement of certain polymers within it might alter its strength," said Professor Paul Dupree, a co-author of the study in Cambridge's Department of Biochemistry. "Understanding how the components of wood come together to make super strong structures is important for understanding both how [plants](#) mature, and for new materials design."

"There is increasing interest around the world in using timber as a lighter and greener construction material," added Dupree. "If we can increase the strength of [wood](#), we may start seeing more major constructions moving away from steel and concrete to timber."

More information: J. Lyczakowski et al. Structural imaging of native cryo-preserved secondary cell walls reveals the presence of microfibrils and their formation requires normal cellulose, lignin and xylan biosynthesis, *Frontiers in Plant Science* (2019). [DOI: 10.3389/fpls.2019.01398](#)

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