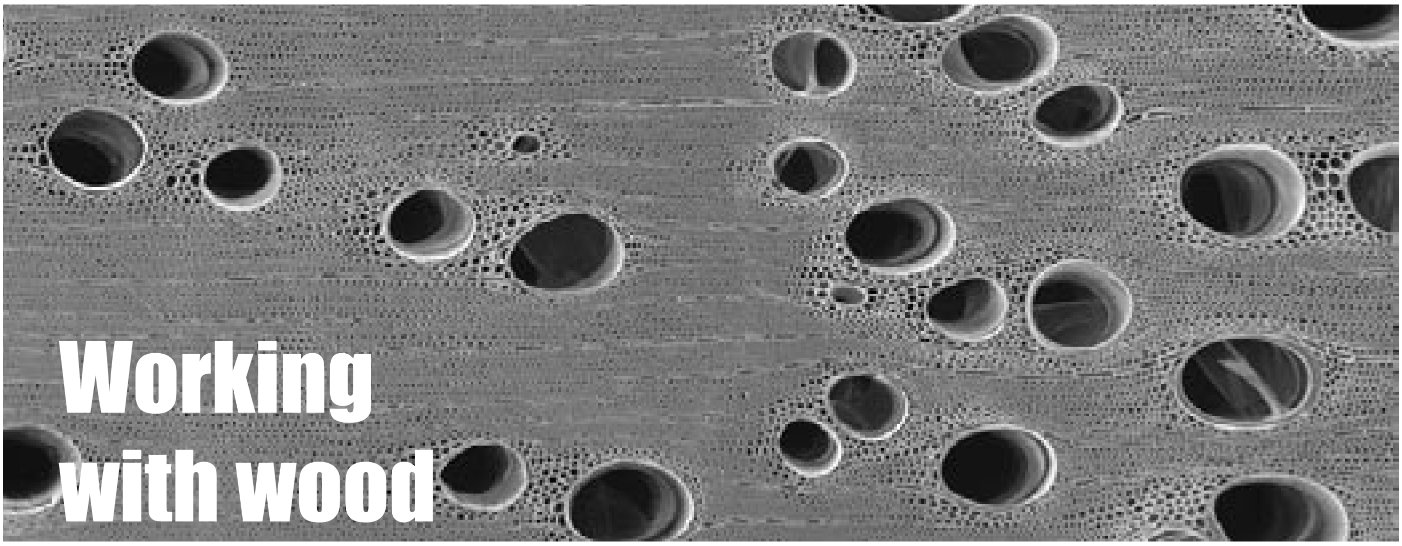
CSEM's

Materials Monthly

October 2005

A world of wonderful wood



The image above was captured by Dr Roger Heady, a Visiting Fellow at the School of Resources, Environment and Society, and an expert on the structure of wood. It shows a transverse section through the wood of alpine ash, one of Australia's classic timbers. (See page 6 for another angle on this wood.)

In this issue we explore several dimensions of one of Nature's most versatile and widely used biomaterials: wood. The Australian National University is working with wood in a number of areas including research on it's structure and function, and new ways to incorporate it in design.

A film of wood

The wettability of tree capillaries is important in the transport of water in living trees, and in practical applications of wood. For example, the impregnation of wood with additives, or the penetration of an adhesive depends on the wetting properties of wood fibres and capillaries. The surface chemistry of wood fibres is also important in the manufacture of paper and related products.

Experiments on individual wood fibres can be difficult, so researchers in the Department of Applied Mathematics (at the Research School of Physical Sciences and Engineering) are attempting to produce stable films of the major constituents of wood to use as model surfaces in studies on the wettability and surface chemistry of wood fibres. These major constituents of wood are the polymers cellulose, lignin and hemicellulose.

The work is being carried out by Dr Shannon Notley, Dr Mika Kohonen and Dr Vince Craig from Applied Maths in collaboration with Dr Magnus Norgren, a colleague from Mid Sweden University. (For more information on the interaction of tree capillaries and water see the October 2004 issue of *Materials Monthly* which carries a story on the research of Dr Kohonen).

"At this stage we have been able to produce smooth, very stable films of cellulose and lignin by spin-coating silicon wafers with solutions of the polymers," says Dr Notley.

"Shannon has already used such films as a model system to study the forces between fibre surfaces. We are now characterizing the wettability of films of the individual wood components," says Dr Kohonen. "The ultimate goal is to prepare composite films, containing all three components, in order to provide a useful model for the wood fibre surface."

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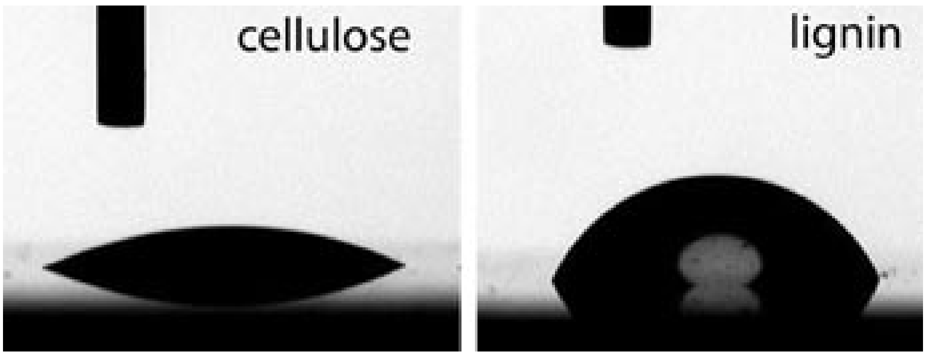
The image shows water droplets on films of lignin and cellulose. There is a clear difference in wettability between the two materials. Water spreads more easily on cellulose than on lignin (ie the contact angle of water on cellulose is lower than on lignin).



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THE AUSTRALIAN NATIONAL UNIVERSITY

Of genes and wood

Colleen MacMillan with Zbigniew Stachurski discussing how the Instron machine behind them can be used to measure the force required to snap a stem of Arabidopsis.

Wood cells originate through a complex process involving cell division of the vascular cambium, cell differentiation and expansion, secondary wall synthesis and deposition, and finally cell death. A large proportion of the wood of trees like eucalypts is made of the fibres associated with the water carrying vessels – cells known as xylem tracheids. The cell wall of such vessels contain cellulose microfibrils arranged in an array around the cell. The angle that the cellulose microfibrils make with the longitudinal axis of the cell is termed the microfibril angle (MFA) and this plays an important role in the stiffness of the wood. CSIRO researchers are investigating the genetic basis of wood formation and have enlisted the aid of materials engineers at ANU to measure the strength of different gene treatments.

"The research in our lab focusses on genes controlling wood formation, and also those that might play a role in cellulose MFA orientation of wood," says Dr Colleen MacMillan, a researcher working at the ensis lab at Yarralumla.

'ensis' is a joint venture between CSIRO and Scion (formerly New Zealand Forest Research). The venture is Australasia's leading supplier of research and development services to the forestry and forest products sector. (see http://www.ensisjv.com/ for more info). Led by Dr Simon Southerton, this project is part of a larger research program looking at various aspects of molecular genetics connected with wood development.

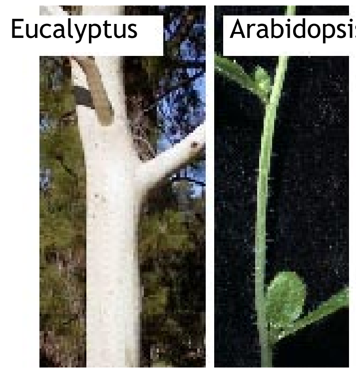
"We know that in eucalypt branches the fibre cells from the top of the branch have a small MFA, whereas fibres from the bottom of the branch have a larger MFA," she says. "Using microarray experiments, we have compared gene expression in developing xylem tissue from the top and bottom of eucalypt of branches, and discovered that a set of arabinogalactan proteins (AGPs), amongst a host of other genes, were differentially expressed."

"We are interested in discovering what function these AGP genes played in the development of xylem tissue. We found that the protein sequence of our eucalypt AGPs is similar to some of the AGPs found in the Arabidopsis genome. Arabidopsis is the model lab plant that most scientists use for studying plant development.

"Not only are these eucalypt and Arabidopsis AGPs related on a protein sequence level, but when we look at where within each plant the gene is expressed, we find something even more interesting.

"In eucalypt trees, our AGP genes are only expressed in the stem vascular tissues, and in particular, the phloem and sometimes only the xylem cells. The gene is virtually not turned on anywhere else, for example in the flowers or leaves or roots. Remarkably, what we found for the eucalypt AGPs was also found for the Arabidopsis AGPs: the Arabidopsis AGPs are highly expressed in stems, with little to no expression anywhere else such as in flowers or seed pods or leaves. These results suggest it's likely that these AGPs are playing a similar role in both plants."

To work out what role AGPs might be playing in wood development, Dr MacMillan is using Arabidopsis as a lab 'guinea pig'. In some specimens of Arabidopsis these particular genes are knocked out – that is, they are not expressed at all. She is then investigating whether there is any difference in properties of the cells in the knock-out line as opposed to the normal plants. That difference might perhaps be a change in cell wall properties like strength and stiffness.



Eucalyptus grow into mighty trees while Arabidopsis only manages to make it to a puny weed but both share common genes that control the strength of their stems.

As part of this investigation, Dr MacMillan is using the Instron universal testing machine in the ANU Department of Engineering with the assistance of Dr Zbigniew Stachurski. The Instron can apply a tensile force to a material and then measure that material's response. In this case it's being used to test the strength of dried stems of the knock-out lines of Arabidopsis against normal plants.

"These experiments are really trying to get to the nuts and bolts of the question – do these genes play any role in cell/wood strength?" says Dr MacMillan. "There are many ways to test strength, and so far we are testing the tensile strength of the stems – that is – basically asking the question 'how much force does it take to break the stem?' To do this we are developing ways to use the Instron especially for our Arabidopsis stems – this is our current challenge. We have had some early encouraging results – but this is still very much a work in progress.

"This research asks some fundamental questions that are relevant to plants in general – eucalypts and Arabidopsis – and the answers might be useful to applied industries like forest products. If it turns out that these AGPs are playing a role in wood strength, then we can screen populations of eucalypts for variants in these AGP genes that might correlate with wood strength, and therefore use these variants in traditional breeding programs."

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Mixing wood, art & science

Working with wood, in many ways, is really another permutation of materials science and engineering. Wood after all is one of Nature's finest biomaterials, and turning it into objects of art or utility requires a detailed understanding of its properties and variability. On top of this is the need for an appreciation and desire for experimentation on how different types of wood can be combined and how a variety of other materials interact with wood over time. This includes adhesives, finishes and the range of materials used structurally or decoratively with wood.

The Wood Workshop at the ANU School of Art provides comprehensive skills-oriented courses of study aimed primarily at students wishing to work as designers and makers. Students are provided with a program comprising of real and hypothetical design briefs, and are encouraged to investigate all aspects of professional practice. They are also given the opportunity to rub shoulders with established professionals, and are exposed to a range of issues such as exhibiting and marketing through a variety of structured Workshop projects.

The Head of the Wood Workshop is Dr Rodney Hayward. An organic chemist by training, Dr Hayward served part of his scientific apprenticeship as a research fellow at the Research School of Chemistry. Though you'll rarely hear him using his 'Dr' title, he's happy to acknowledge his previous life and commitment in science. Indeed, he is firmly of the belief that it forms a vital part of his what he brings to the Workshop.

Rodney Hayward next to a display case he designed and built using Huon pine and celery top pine. The case was created specifically for a violin and its bow. The violin is being built by David Morgan (see box on Making music from maple).

"At the core of my creativity is a love of investigation: a love of insight into the subtleties of structure and design: the how-and-why as we understand it at the moment." he says. "Into my work I have incorporated the knowledge, rigor, and manual finesse from a career as a research chemist.

"Good design in wood is more than using its intrinsic qualities — it is about seeking structures that are tough yet delicate like the tracery of construction in the trees from whence the wood came. Wood is a sustainable composite polymer. Yet, wood is also the skeleton of a life. When I work I try not to lose sight of the tree, and I attempt to have our students see that as well."

And good design is something Dr Hayward attempts to get all his students to engage in.

"In the first instance that means explicitly stating what it is you're aiming for in your design," he says. "That might be capturing some aspect of spirituality, or serving the functional requirements of a child or fulfilling some aim of sustainability."

For examples of innovative design coming out of the Workshop see the October 2004 issue of Materials Monthly for the story on 'butterfly tables' making use of plantation grown timber. The December 2002 issue discussed 'air furniture' which combined thin plywood and extruded styrofoam. And consider the breakout box on a commemorative table for the Mount Stromlo Observatory.

Over the years Dr Hayward has encouraged his students to consider other ways of seeing materials and especially wood. They are exposed to some of the research happening in other sections of the university such as the work on carbon fixation and photosynthesis at the Research School of Biological Sciences and the CSIRO. The Wood Workshop has also hosted a number of exhibitions that examine wood and other materials at different scales and through other eyes. These have included a display of Dr Roger Heady's electron microscopy (see the March 2002 issue of Materials Monthly) and Ian Percival's photography.

At work in the Wood Workshop. As part of their course, second year students are required to make their own work benches. These are some of the finest (most elegant) workbenches you'll find anywhere. "It's sometimes a challenge for us to prevent students from creating workbenches the size of aircraft carriers," comments Rodney Hayward.

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Rising like a phoenix

A good example of how the origins of a piece of wood can be inextricably linked to the design, form and function of the final work can be seen in a commemorative table that has been created by Peter Giles, a recent graduate of the Wood Workshop.

Using a selection of timber oddments salvaged from the charred hulks of trees left around Mount Stromlo Observatory following the 2003 wildfires, Peter was commissioned by the ANU to design and build a table that will one day stand in the rebuilt Administration Building at the Observatory.

"The timber I had to work with was Atlantic cedar " says Mr Giles. "This is incredibly soft wood that you wouldn't normally use in furniture design as it would quickly become scarred by everyday use. However, for the purposes of a commemorative table this becomes less of a problem."

The challenge then was to create a design that reflected the astronomical purpose of the Observatory while observing the impact of the wildfire. And his solution is both simple and elegant.

"The table's form incorporates a variety of curved lines and forms evoking the arcs and traces that are so common in astronomy and astronomical equipment, and the building in which it will eventually be housed" says Mr Giles. "There is a curving break across the table surface towards one of its ends symbolising the rupture caused by the fire between past and present. At the narrowing end of this rupture, the gap is bridged by an inlaid circular bezel containing fritted glass from a glass lapping blocks used to make telescope lenses destroyed in the fire."

He is now working on a second commissioned project using timber sourced from the same batch of salvaged timber that the observatory table was created from. This second table is to be placed in the halls of new Parliament House.

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A commemorative table produced from timber left after the wild fire of 2003. (Above) A bezel of fritted glass bridges the rupture arcing across the table top. (Below)The table's maker, Peter Giles, with the table and a piece of the salvaged timber.

Mixing wood, art & science
(continued from page 3)

Equipment available in the Workshop includes all facilities required to undertake design and construction in wood including lathes for wood and metal, jointers, thicknessing planer, veneer press, resaw, band saw, dimension saw and vacuum equipment for laminating. Each student is allocated an individual workspace and is expected to supply their hand tools. In addition, through the Complementary Studies Program, students can access the resources of other Workshops within the Art School, including the three dimensional modeling and design facilities offered by the School's Computer Art Studio.

The Workshop has an active program of distinguished visitors and artists-in-residence from Australia and overseas whose specialist expertise complements the teaching of the incumbent Workshop staff. Visiting artists and other professionals in the field interact with students through workshops, lectures and demonstrations.

The Workshop is part of the ANU School of Art, and forms a part of the ANU Faculty of Arts.

More information: http://www.anu.edu.au/ITA/CSA/wood/index.html

"Nowadays we cannot ignore the science that underlies and explains an art: it often helps us reproduce what is old, often to invent what is new. And science, although it cannot tell us how to make a beautiful object, can frequently instruct us how to prepare a material capable of beautiful expression in the way of form, or surface, or colour; and surely the scientific analysis of the beautiful does not lessen its charm while adding to it fresh intellectual interest."

Sir Arthur Church (1834 – 1915)

The Wood Workshop has hosted many exhibitions on different ways of seeing materials. (Left) The opening of a display of Ian Percival's photography. (Above) Rodney Hayward with Roger Heady at a display of Roger's electron microscopy.

Making music from maple

Possibly the greatest testament to the durability and reliability of timber and good design can be found in the body of a good violin, an instrument which viewed simply is crafted from a few pieces of maple and Italian spruce, held together with hide glue and protected with few coats of varnish.

"A violin might be centuries old and yet, if made well, can still be used daily today and produce an exquisite sound," says David Morgan, a violin maker trained in Europe and currently visiting the Wood Workshop. "Indeed, a fine violin actually sounds better over time.

"And in the hands of a good musician and a traditional orchestral situation that instrument can stand out against an orchestra without additional amplification.

"What else so old is still in daily use today"

David Morgan was born and raised in Canberra, but spent much of his life living and working in Europe where he trained in violin making at the Mittenwald violin making school in Germany.

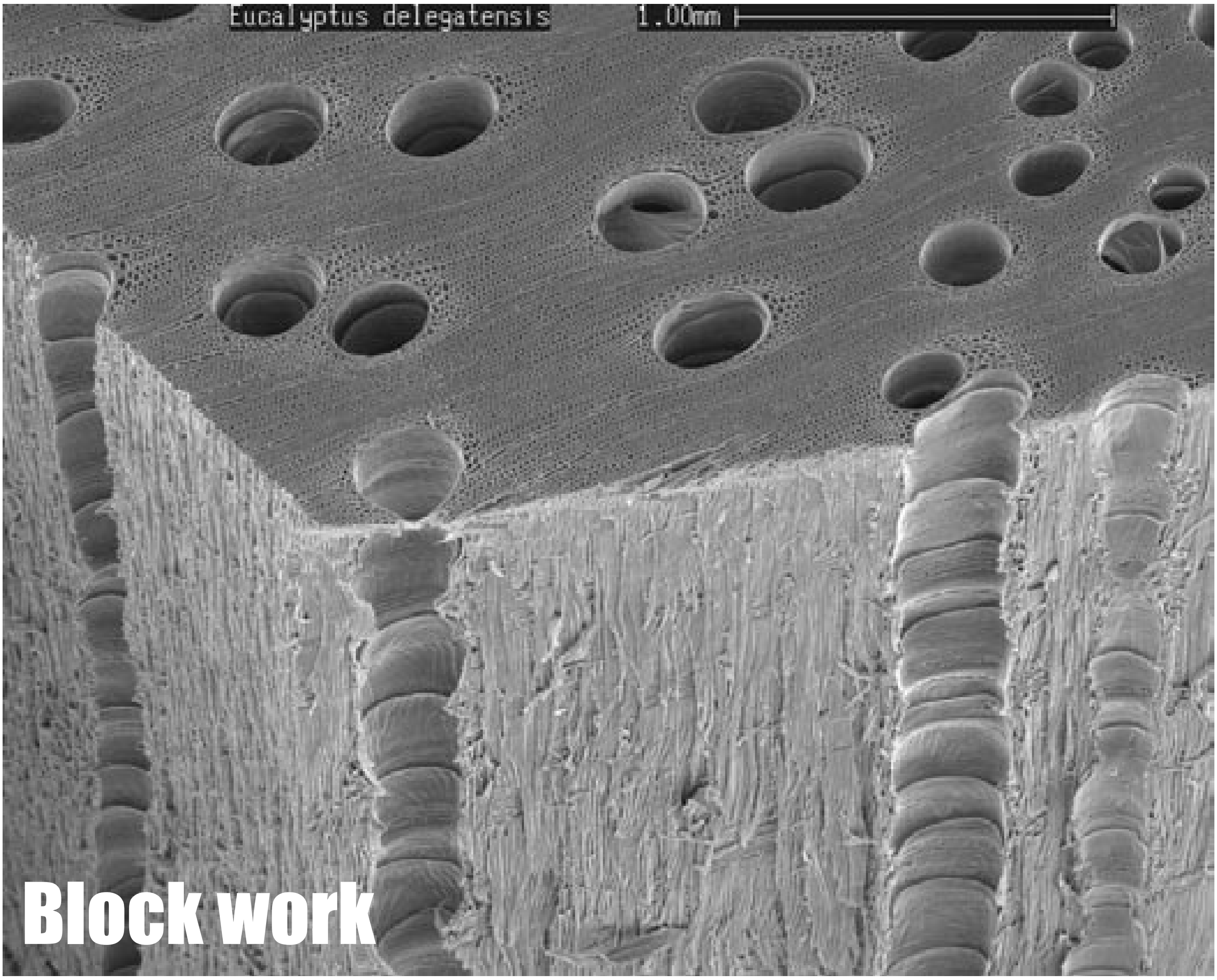
"The profession of making violins is deeply respected and has a rich tradition in Europe,' says Mr Morgan. 'The Mittenwald School is an example of this and, while I was there, had a compliment of seven full time and several support staff instructing 36 students in the art of making violins. It can be a very personal and intense experience."

Unfortunately, while it takes a lot of training and much experience to build a fine violin, Mr Morgan says very few fine instrument makers make a living from building new violins. Their main employment is repairing and restoring existing instruments, which is one of the reasons he's enjoying his time in the Wood Workshop.

Rodney Hayward is praising of Mr Morgan's skill and experience in the art of fine instrument making and has wondered whether it might be possible to establish a centre for musical instruments at the ANU.

"The ANU has considerable expertise in materials science, the physics of musical instrument, wood craft and music," he says. "Wouldn't it be wonderful if we could draw on these strengths and create a synergy that might see the art and science of musical instruments rise to new heights."

David Morgan and the violin he is making at the Wood Workshop



Block work

Pictured here is a scanning electron micrograph of the corner of a block of alpine ash wood (*Eucalyptus delegatensis*) which shows the structure of the wood. The scale bar in the top right of the image is 1 mm.

The large pores are vessels – specialized cells for carrying water from the roots up to the leaves of the tree. The small-sized cells closely surrounding the vessels are called parenchyma. The top of this block of wood represents a transverse section through the wood. The sides of the block cut longitudinally through the wood and have sliced through four vessels. This image shows that each vessel is composed of many vessel elements connected to each other and forming a continuous pipe.

This image (and the one on the cover page) was taken by Dr Roger Heady, a Visiting Fellow at the School of Resources, Environment and Society (formerly with the Electron Microscope Unit). Dr Heady's research interest is the microscopic structure of wood. He carried out pioneering studies on native cypress and the famous Wollemi pine, though he's interested in wood of any description and has carried several studies on Aboriginal bark paintings.

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2005 CSEM Prizes

Do you know an undergraduate student who might be in the running for a CSEM Prize in 2005?

Each prize is worth $2,000. The beauty of the awards is that they don't require the students to go to much additional work to enter. All they have to do is submit a copy of their final year thesis to the Director of CSEM by the 30 November.

For full details see: http://www.anu.edu.au/CSEM/prizes.php

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