ScionConnections

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Around 2.4 million tonnes of bark is produced annually by the New Zealand forest industry.

Bark biorefinery progress

Around 2.4 million tonnes of bark are produced by harvesting New Zealand forests every year. The availability and recovery of bark is set to increase as more logs are debarked before being exported. How can we use this resource better?

Bark is a tree's suit of armour, protecting the tree from infection and insects, sun and weather. It keeps the sap in and growth of delicate wood cells safe. But once a tree is harvested bark can become a liability. It needs to be removed for wood processing or pulping, or if left on logs, it can provide hidey holes for wood boring beetles on logs for export.

The compounds in bark that help protect and keep trees healthy are valuable biochemicals offering antioxidant, antibacterial, waterproofing properties and many other uses. The prospect of extracting these high value chemicals is one of the motivators behind what has become the Bark Biorefinery Project, a five-year Scion-led research programme supported by the Ministry of Business, Innovation and Employment's Endeavour Fund.

The work started in late 2018 with Scion researchers working with local and international collaborators to develop green-chemistry methods to extract and refine the array of chemicals found in bark.

Bark-based products

Scion's Dr Laura Raymond, working with Pharmalink in Nelson, has carried out an industrial scale extraction of pine bark. One product from this extraction trial is a mixture of soft, natural waxes much like petroleum-derived paraffin wax. Work will continue at Scion to separate and purify these natural waxes, which could be used as waterproof or water repellent surface coatings, and in cosmetics and skin care as emollients, for example. Extending this work, Dr Dawn Smith is investigating

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Critical capability for New Zealand

In previous editorials I have mentioned how the world's move to a circular bioeconomy presents a new future for New Zealand.

In my conversations with people I have often quoted Stora Enso "Anything made from fossil-based materials today can be made from a tree tomorrow" to illustrate the magnitude of the potential change we are talking about. And, of course, there are many other purposes and benefits we obtain from growing forests and trees.

Our research in forest plantation management earns us international respect and following. More forest productivity gains are possible through silviculture, advanced breeding and genetics.

I have also pointed out that the world is moving to smaller scale manufacturing (sometimes called distributed manufacturing) and the relevance of going small to our regional economies.

Now, I want to reflect on the world-leading enabling research that goes on here at Scion. Our number one priority is providing the research capability and confidence for New Zealand to plant and grow healthy and resilient forests. This is critical for New Zealand.

Our research in forest plantation management earns us international respect and following. More forest productivity gains are possible through silviculture, advanced breeding and genetics. Our scientists along with industry partners could develop trees and methods that will double current growth rates. We know this from the data already amassed on radiata pine, and we have barely started researching indigenous species for production forestry. What has been learned however may surprise you, as we described in the last *Scion Connections*.

Protecting our forests (plus people and property) is vital too. Scion's rural fire research team is fielding many queries from media outlets wanting to learn about the increased occurrence of extreme fire worldwide and the way it behaves and what this means for our country. Since the team's inception almost 30 years ago, it has worked closely with other international experts and is known for its expert capability.

Alongside the fire researchers are Scion entomologists and pathologists who have a long, proven record of swiftly responding to biosecurity threats. Working collaboratively with other teams they are tackling menaces like kauri dieback.

One of the challenges Scion faces is getting our knowledge out more widely and used by more who would benefit. To help promote our research and technology we have invested in an innovation hub to both showcase what is possible from our forestry resource and to increase the interactions staff have with the forestry and wood processing sectors and yet-to-be-established industries.

Our next goal is to establish biopilot facilities to allow scaling up of our new materials research so that New Zealand industries can trial innovative materials beyond laboratory scale and undertake de-risking activities without having to go offshore.

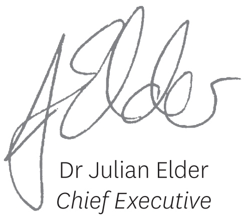
Strategic partnerships are key to our success also. We have such a partnership with Te Uru Rākau, and it is good to see they have an outreach role. Other strategic partnerships are sought, particularly those where we can undertake work that leads to demonstration sites or applicable tools. We are interested in partnerships in both growing or manufacturing sectors. Another example is the highly erodible lands work we are doing with Hawke's Bay Regional Council (see *Scion Connections* issue 33, September 2019).

Scion is a huge asset for New Zealand, recognised globally for our leading research in forestry and the circular bioeconomy.

Scion is a huge asset for New Zealand, recognised globally for our leading research in forestry and the circular bioeconomy. Here at home, we need similar recognition for the knowledge and opportunity we provide in developing next generation, renewables-based processing and manufacturing industries.

As I've said before, I'm committed to seeing Scion help lead New Zealand's transition to a circular bioeconomy. The global drivers for such a transition surround us, we're a nation of inventors, our scientific expertise is plentiful, and forestry can be a key enabler. What's stopping us recognise what's needed to transform our country to a sustainable way of living and consuming?

I welcome your thoughts on this topic and any other matter raised in this newsletter.



Dr Julian Elder
Chief Executive

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Dr Florian Graichen speaking at the Victoria University of Wellington, School of Policy and Government workshop on policy and management.

Circular bioeconomy Q&A

System-wide changes such as transitioning to the circular bioeconomy require unprecedented collaboration and transparency across industries, government and community. It presents a huge challenge for the next generation of policy makers that will help to transform our economy into this new circular model. They will be creating policy for a world that faces environmental, social and economic problems and fundamental uncertainty.

Professor Girol Karacaoglu, Head of the School of Policy and Government at Victoria University of Wellington, is faced by this very dilemma. To prepare his policy and management students, Professor Girol decided to expose them to the diverse elements (including finance, policy, leadership, resilience, environment and innovation) of the linear to circular transition. Girol invited Scion's Andrea Stocchero and Florian Graichen to speak with his audience of future policy makers about the role of 'innovation' in the circular bioeconomy and in circular cities.

Following their time with the students, Girol (GK), Florian (FG), and Andrea (AS) shared their perspectives on this transformation.

Why do we need a circular bioeconomy in New Zealand?

FG: The transition to a circular bioeconomy in New Zealand is a golden opportunity for our generation. We can create value chains from gene to product that meet increasing sustainability demand onshore and internationally. If we transition our economy now, New Zealand in 2050 would have a high tech, resource-efficient and competitive economy with zero net greenhouse gas emissions.

AS: The current linear economy model has proven unfit to provide urgently needed solutions to stop, reverse, or even mitigate current trends like climate change, resource depletion, in the context of rapidly increasing population growth. The circular bioeconomy is an important component in achieving future resilience, adaptability and sustainability.

GK: We have no idea what future generations will value and how they will want to live. We require an economy and society that ensures opportunities – we need to prepare 'the garden' that will provide them with the opportunities to *survive and thrive* – i.e. flourish, as they live the lives they value, in safety.

Transition to a circular bioeconomy will make it possible for individuals and communities to live the kinds of lives they value, in the present and into the future without compromising others' rights to do the same.

How do we kick start the circular bioeconomy transition in New Zealand?

FG: A key enabler would be a national circular bioeconomy strategy for New Zealand. We need a triple helix model of transition - including academia, cross sectorial industry and government - to ensure all opportunities and challenges are identified.

AS: Recognising and mapping the widespread and interconnected benefits that circular bioeconomy would bring to New Zealand's society, economy and natural environment, is necessary to generate the momentum and traction needed to deploy such transition.

GK: Intergenerational wellbeing has to become a more dominant government objective. Parliament should specify intergenerational wellbeing as the core objective of public policy. Furthermore, through appropriate legislation, it declares that each government will be held accountable for pursuing public policies that promote intergenerational wellbeing – now and in the future.

Why is collaboration the key to success?

FG: Successful transition will require not only new technologies but also the sharing of value and risk across all participating sectors and government. Companies and whole industries that traditionally were operating in separate value chains will have to work together and be linked in new value networks.

AS: A holistic, integrated, systems approach is necessary to harness interdependent opportunities across value chains, sectors, the economy, the community and the planetary systems. The transition to circularity will require the expertise and capacity generated from new collaborations and synergies across those same areas and systems.

GK: What is most important is the degree of inclusiveness of these processes. The fact that individual and family lives are lived in social settings, and the imperative of social cohesion for sustainable wellbeing, makes collaboration and community engagement as full participants with the whole public policy and management process critical.

To read the full version of this interview, visit scionresearch.com/circularperspectives

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Identifying pōhutukawa for myrtle rust response

Part one of our feature on Scion's recent advances in deep learning technology.

Deep learning is a process where computers 'learn' to recognise complex patterns by looking at thousands of examples, reaching human-level accuracy for some tasks. The basis of deep learning technology has been around for decades, but it has been limited to theory more than practice because computer processors have not been able to keep up. That is not the case anymore. Huge increases in modern computational power, some nifty mathematical tricks and large datasets have enabled deep learning technologies to thrive and be integrated into our everyday lives.

At Scion, we see huge potential for deep learning to make unprecedented gains in many areas of our work. We are embracing deep learning in biosecurity, forest inventory and phenotyping, and forestry genetics. The following examples from our work with deep learning are showing promise across a variety of fields.

Biosecurity benefits

Part of the response to any biosecurity incursion in New Zealand involves mapping and identifying the host species of the pest or pathogen. This is a standard part of managing the incursion and helps managers to predict where the pest or pathogen might show up next.

When the myrtle rust plant pathogen was first found on the New Zealand mainland in May 2017, there was immediate concern for our 37 native myrtle species, as well as the introduced myrtles. One of the most precious species at risk is the pōhutukawa (*Metrosideros excelsa*).

The pōhutukawa is highly valued culturally and an iconic feature of many kiwi beaches. It also grows as an amenity species in Australia, where observations showed that the species is susceptible to myrtle rust.

The conventional next step after an incursion is to send hordes of trained personnel to infection sites to locate host trees and inspect them. This is a difficult task to complete on a large scale. Trees can be spread across a mixture of public and private property or in hard-to-access areas. Carrying out large-scale searches is also very costly and time consuming.

Deep learning models overcome many of these barriers. They show incredible potential for fast, large-scale tree species identification using aerial imagery with only three colour channels (RGB) the same type of imagery your mobile phone can capture.

Scion researchers Drs Grant Pearse, Alan Tan and colleagues have found great success with deep learning technologies. With support from the Ministry for Primary Industries (MPI) they have put this technology to work looking for pōhutukawa.

Searching for pōhutukawa

Traditional tree detection models often use lidar and multi-spectral imagery to capture features specific to species. Developing methods using this approach can be complex, subjective and costly for acquisition of the multi-spectral imagery and lidar. In contrast, deep learning models use pre-labelled images to learn the hard-to-quantify features and appearance that make objects visually distinctive to humans. With enough low-cost imagery, the models can achieve state-of-the-art classification accuracies.

For their pōhutukawa identification experiment, Grant was supplied with a huge amount of data collected by AsureQuality for MPI when they manually searched Tauranga and surrounds for pōhutukawa in 2017 and 2019. In 2017 there was little to no evidence of flowering in the imagery, but in 2019, the red blossoms covered the canopies. This provided Grant and his team with the ideal data to train and test their models on.

Using the 2019 imagery, the deep learning model could easily identify pōhutukawa based on the characteristics of their distinctive red flowers. With the imagery from 2017 (no flowers present), the model began to discern common traits of pōhutukawa that are present all year round, including their multi-leader crown shape, buds or seed capsules, and the texture and blueish hue created by the large waxy and elliptical leaves.

Results

When the pōhutukawa were in bloom, the deep learning model produced a near-perfect classification of 99.7 per cent accuracy (only 2 mistakes out of 569 samples), despite the level of flowering varying substantially. Without the distinctive flowering, the deep learning model still achieved 95.3 per cent accuracy despite significant differences in the appearance of the pōhutukawa.

Grant says, "Generalisability is the goal of any species classification model. We want to know if the model might be useful elsewhere in New Zealand. This is especially important for biosecurity applications where we need accurate, fast detection to manage incursions."

"To test this, we combined datasets from 2017 and 2019 to assess the technique in real-world conditions, where flowering and imagery sources will differ. The combined model's results were high at 98.1 per cent accuracy, suggesting there's

huge potential to generalise to real-world, large-scale biosecurity mapping applications."

As a comparison, Grant, Alan and the team also used more traditional spectral-based remote sensing techniques to perform the same tasks. The spectral-based models did not perform as well, only detecting 88.1 per cent (with flowering), 80.0 per cent (without flowering) and 84.9 per cent (combined).

Limitations

The accuracies observed in this study were only possible with high-resolution imagery (10 cm = 1 pixel). A brief test conducted by reducing the resolution of some of the imagery showed that the accuracy of the model declined rapidly as the distinctive features of trees were lost, with 15 cm simulated imagery showing only 70 per cent accuracy.

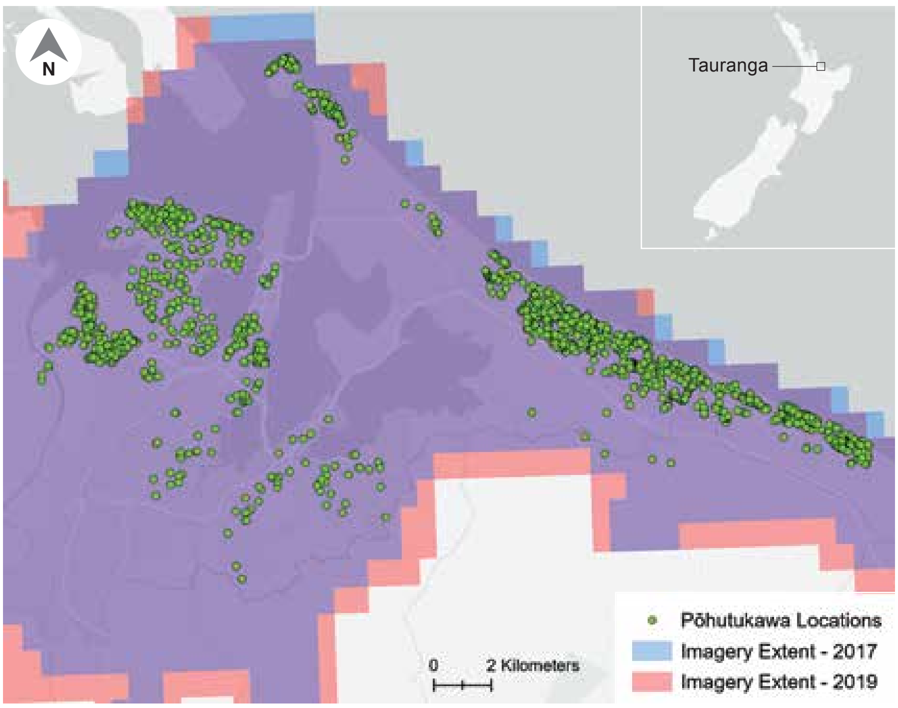
These models also need large amounts of training data. In this case, the number of samples (1139) was very large compared to other tree identification studies, but quite low by the standards of deep learning model development. A key finding was that key plant traits, such as flowering, can be used to help identify enough trees to train a large deep learning model. Adding data from more images of the same scenes at different times, we can train a more generalisable model.

Potential for use in biosecurity responses

Grant's experiment has proved that applying deep learning methods to identify potential pathogen hosts is possible using readily available, low-cost imagery and that it could be used to support future biosecurity efforts. The simple RGB aerial imagery required is already routinely captured over large areas of New Zealand.

With more training data and higher-resolution imagery, the deep learning approach could be expanded to a broader range of species across New Zealand. How well it performs will depend on how visually distinctive the target species are and at what resolution these features are distinctive.

The future, Grant says, is in predicting what will arrive in New Zealand next, and preparing by mapping host species before the pest or pathogen makes landfall.



FOR FURTHER INFORMATION on this project contact Dr Grant Pearse at grant.pearse@scionresearch.com

Surveying seedlings for precision forestry

Part two of our feature on Scion's recent advances in deep learning technology.

In the last few decades, the forestry sector has embraced a range of new precision management tools and techniques to manage forests on a new scale. Precision management is based on the concept that big productivity gains can come from smaller-scale, tailored management techniques. To continue this evolution, the forestry sector will require new technologies for data capture, giving rise to a suite of new, nuanced management methods.

Deep learning has the potential to play a large role in this transformation. Scion is pioneering a new deep learning-based system that uses low-cost visual (RGB) imagery collected by UAV (unmanned aerial vehicle) mounted cameras that can identify and map radiata pine seedlings. The algorithm that has been created could soon replace manual surveys, which are laborious, expensive, sometimes dangerous and only suited to small areas.

Scion's initial deep learning models detected seedlings with extremely high accuracy. Between 94-98 per cent of seedlings in a range of test sites and landscapes were identified. This year, the team has taken that technology one step further, and we can now detect and pinpoint the location of each seedling.

How did we do it?

The process begins by gathering high-resolution imagery from a UAV, stitching it together, scaling and geographically aligning it – creating an orthomosaic. This provides an accurate way to connect objects in the imagery with precise physical locations that can be utilised by the algorithm. A key development of this work was to prepare this imagery using a 'tile and buffer' approach. This ensures small objects like seedlings are not lost when these large orthomosaics are fed into deep learning models designed for use on images from a smartphone.

Scion scientists Drs Alan Tan and Grant Pearse worked with Dr Matthias Franz from Hochschule Konstanz University in Germany to test their approach at Rangipo in the central North Island. The site was pastureland that has converted to an experimental forest establishment trial as part of Scion's Growing Confidence in Forestry's Future programme.

The model was given part of the dataset (imagery and field measurements with spatial data) that had many seedlings pre-identified to teach it how to recognise them. As there were so many seedlings the model could only be given a point to represent the seedling's location. This is unusual for deep learning, which usually requires a 'bounding' box carefully drawn around the objects.

What were the results?

The model achieved a very high detection rate of 99.5 per cent and only missed 16 of the 3014 seedlings in the dataset. The false negatives occurred where seedlings were undetected due to dense weed cover. There were also a few false positives caused by tall weeds being identified as seedlings.

The model's performance was impressive. It only needed point locations for training which dramatically reduced the time and cost that would have been needed for traditional methods. The field measurements also played a big role in revealing seedlings hidden by weeds that would have been missed otherwise. Overall, the error rate remained very low and many seedlings hidden in weedy areas were still correctly detected.

Big picture

Seedling detection using remotely sensed data and deep learning techniques could provide a more efficient, safe and accurate assessment of stand densities and a way to accurately map seedlings. There are a range of tools that this individual tree level data could lead to in the future, including precision weed and disease control operations from UAVs and tree-level inventory.

In the coming years, New Zealand will need to plant a lot of trees to meet our goal of net zero carbon by 2050, and to provide more wood fibre-based resources for the future. Precision forestry techniques, like deep learning, will enable future forests to be optimised for productivity, sustainability and health, ensuring our forests meet their full potential.

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New research nursery facilities

Scion's research nursery has been upgraded with new facilities and demonstrations of state-of-the-art machinery not yet used in New Zealand forestry.

The facilities are pilot scale, but show how a modular, automated, lean-flow, environmentally sustainable propagation facility could work in New Zealand conditions.

Year-round propagation

With our upgraded facilities, cuttings can now be propagated at any time of year. The upgrade includes an enclosed growing area with automated climate controls. The facility will also allow us to do parallel testing of different environments, speeding up the research and development required to develop plant propagation solutions.

Enclosed hedge tunnels and mini hedges are another new feature in the upgrade. Used for indigenous and exotic species, these miniature motherstock are novel in New Zealand. They provide savings in time, labour and space.

New machinery

An automated paper pot sowing line, on loan from Ellepot, is one of the key pieces of new technology. Paper pots will now replace plastic potting bags for most seedlings as we demonstrate this technology.

Another key feature of the upgrade is the automatic tray washer that cleans so thoroughly it prevents the spread of weed seed. The nursery team is enjoying the benefits of the washer, which has led to roughly 90 per cent fewer weeds.

Investing in our staff

Our nursery staff are what keeps the place going, and the new facilities will significantly improve many of the nursery processes for them, while also making their work more diverse and rewarding. Team members are also undertaking training and gaining new qualifications to recognise their skills.

In an industry plagued by labour shortages, we are committed to investing in our talented staff and helping to grow their careers in horticulture.

Research trials

The nursery is set up to test rooting and growing environments for seedlings, cuttings and tissue culture propagation. If you are interested in running a trial in 2020, get in touch soon.

Special thanks to PrimeHort and Ellepot for their support.

FOR FURTHER INFORMATION
contact Nursery Research Manager Craig Ford at craig.ford@scionresearch.com

Bark biorefinery progress

(Continued from page 1)

new bark-derived water-repelling (hydrophobic) polymers as sustainable alternatives for petroleum-based materials used in many products such as paper coffee cups, rainwear or touchscreen coating technology.

Project leader, Dr Warren Grigsby, says this is a great, early win by the Scion team to already be working with one of our New Zealand partners at industrial scale and to come away with such a successful trial is a bonus.

The extraction of tannins to treat leather is another avenue being explored by an analytical team led by Dr Stefan Hill and a wide range of researchers at Scion. Although tannins have been used in the leather tanning process for centuries, most processes today use chromium, which is toxic both to humans and the environment. This part of the project team has been working with New Zealand-based partners to identify and use the right tannin fraction for leather tanning, opening possibilities for producing environmentally friendly, luxury New Zealand leathers.

As part of the overall project a detailed study of compounds in pine bark is being undertaken. This ability to identify and separate chemicals across the different extracts and fractions obtained from bark is key for a successful Bark Biorefinery to produce a range of different products.

Once the extracts have been recovered and isolated from bark, the remaining bark residues retain a high energy content and could be processed into bark briquettes (bio-coal) for use as a renewable energy source. Peter Hall has been forming bark and bark residues into briquettes to give robust, energy dense products that can be easily handled and transported for use in boilers and furnaces.

Circular bioeconomy processing

The biorefinery concept stretches beyond bark. The approach can be applied to many of New Zealand's biomass streams. Scion's Science Leader for Biopolymers and Chemicals, Dr Florian Graichen, considers the Bark Biorefinery programme as a critical step for the transition of New Zealand to a circular bioeconomy and to meet many of the Government's goals for an environmentally and economically sustainable future New Zealand.

FOR FURTHER INFORMATION
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Building a roadmap to New Zealand's New Plastic Economy

Since Scion's New Plastic Economy (NPEC) roadmap project was launched in May 2019, plastics have continued to capture a large share of public attention.

The NPEC began as an initiative of the Ellen MacArthur Foundation. It was an invitation to countries, companies and organisations to commit to ridding the world of plastic waste using circular economy principles.

A total of 13 other countries published NPEC initiatives, roadmaps or action plans in 2018-19. In New Zealand, the Office of the Prime Minister's Chief Science Advisor launched its 'Rethinking Plastics in Aotearoa New Zealand' report, and the Royal Society of New Zealand also published the 'Plastics in the Environment' report. These documents have helped to clarify and accelerate discussion about the plastic issues facing our nation.

While New Zealand is unique, we share common goals with countries like Finland. Scion's NZ-NPEC roadmap lead researcher Marc Gaugler says, "The Finnish NPEC strategy connects different sectors of the economy with their new approach to plastics. They aim to integrate a NPEC-aligned plastic sector with the existing bioeconomy goals by using existing biomaterial conversion in the pulp and paper industry and beyond". This is in line with emerging international signals, such as the recently published Green Deal and Europe's new "Circular Economy Action Plan", which links circular and bioeconomy systems.

New Zealand's plastics industry is invested in developing solutions. Through our work on a New Zealand specific NPEC roadmap, we have joined forces with Plastics New Zealand, Packaging New Zealand, WasteMINZ and the Sustainable Business Network. Together, we will chart New Zealand's path towards a NPEC.

The roadmap team will create a material flow map that aims to track different plastics as they move between organisations in the industry. Marc explains, "We know how much raw plastic material is imported into New Zealand, but we have very limited knowledge about which material goes where and when, across the whole value-chain.

However, Marc is unrelenting. "As a country, we need to work it out, because pursuing this data and level of detail is crucial to make the right changes and identify what specific actions are needed to shift to a New Plastics Economy."

This two-year project is funded by the Ministry for the Environment's Waste Minimisation Fund. The final 'New Zealand - New Plastics Economy Roadmap' will be completed mid-2021.

FOR FURTHER INFORMATION on the NPEC roadmap contact Marc Gaugler at marc.gaugler@scionresearch.com

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