The Failure of Forks

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NWTOG Meeting

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MANCHESTER 1824

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Why research forks?

- Many structural failures of trees relate to the splitting of tree forks
- The ultimate aim of this research is to give useful guidance on the relative safety of forks with included bark. It is hoped that this will be of use to tree inspectors, surveyors and other arboriculturists around the world

Forks with included bark

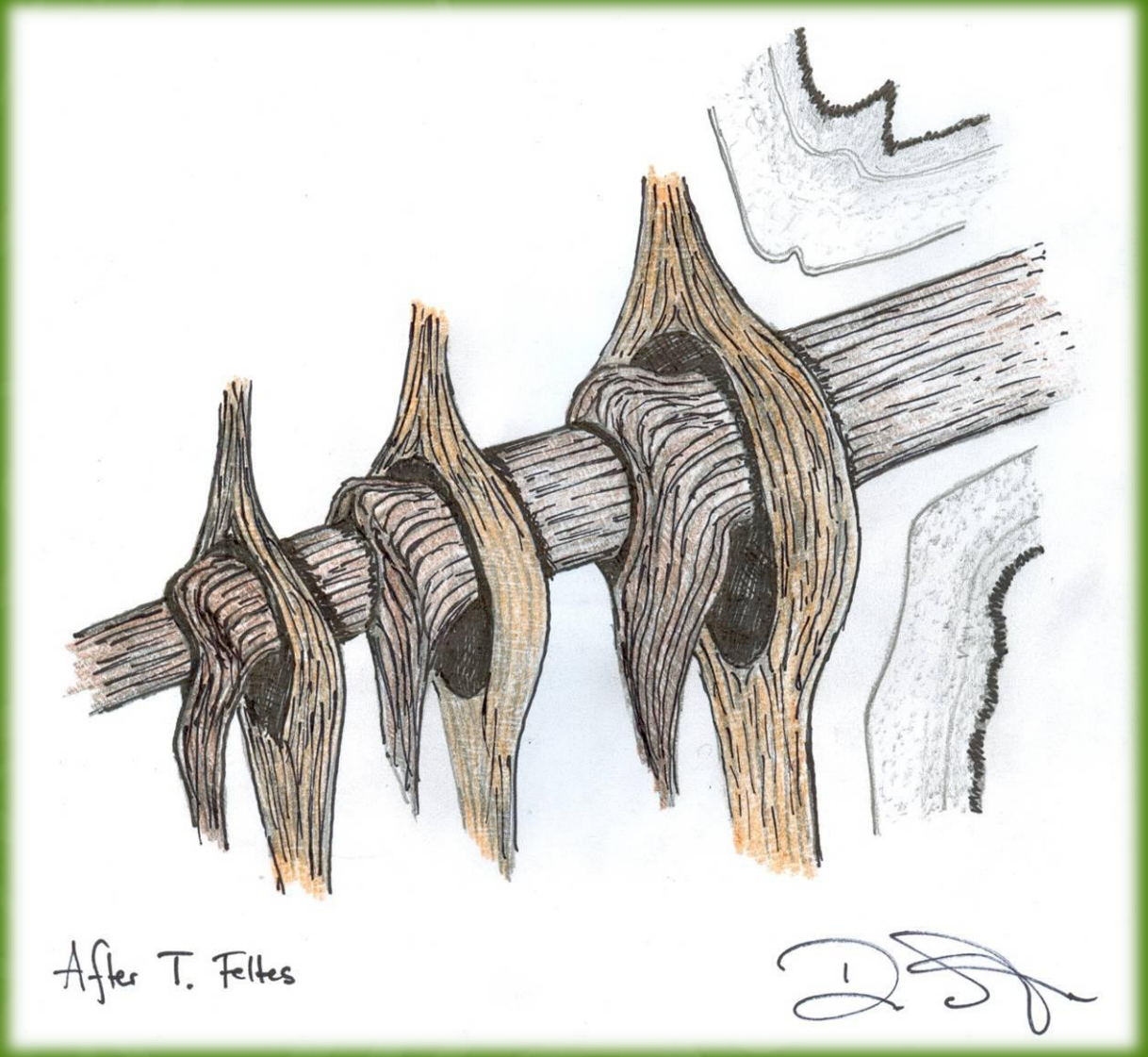
A Summary of Current Findings

- A new anatomical model for tree junctions is needed
- A new set of mechanical models for fork and branch failure is needed
- Forks vary considerably in strength due to their morphology – saying co-dominant stems are weak is currently unjustifiable

A Summary of Current Findings

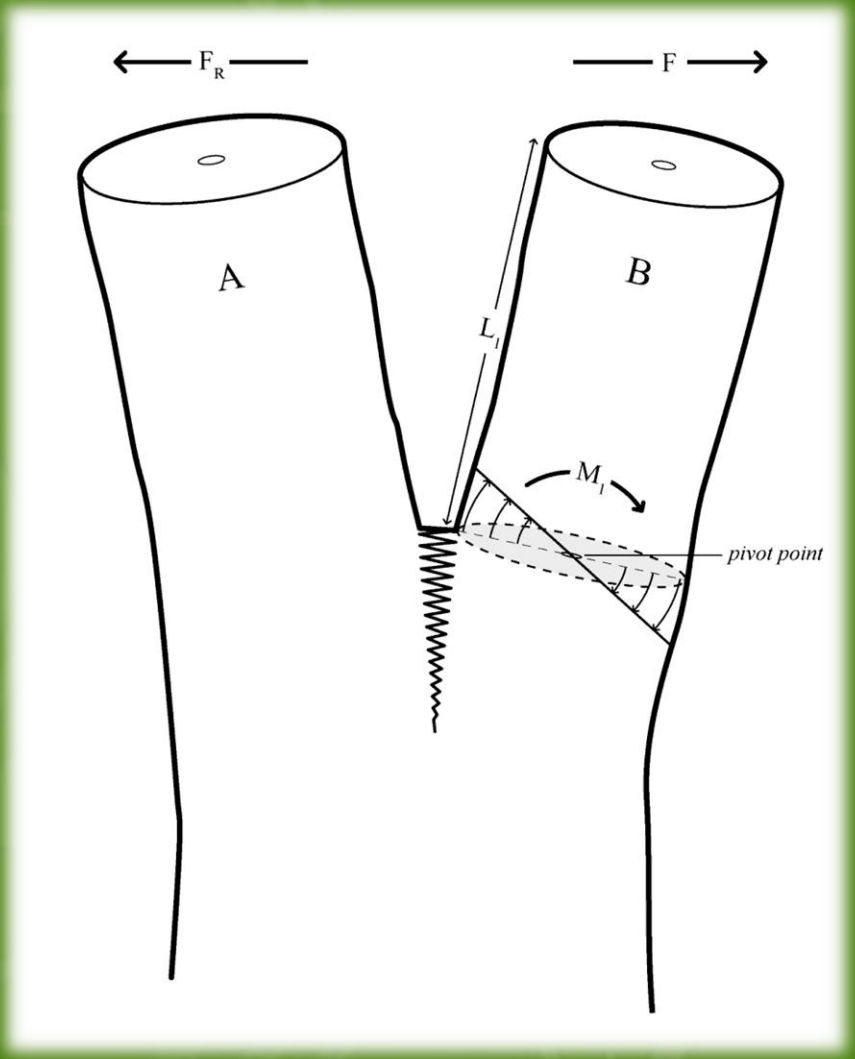
- There would appear to be two distinct modes of failure for tree forks, when they fail under tensile stresses
- Forks can be much weaker than their arising branches – or almost as strong
- The centre of the top of a fork attachment confers the most strength by area to the fork

The old model of branch attachment



A branch or a co-dominant stem?

The old form of mechanical modelling



Denser in the middle

- The vast majority of forks tested so far (over 450) have proven denser at their centre
- This denser zone lies under the branch bark ridge
- An exception appears to be *Quercus robur*

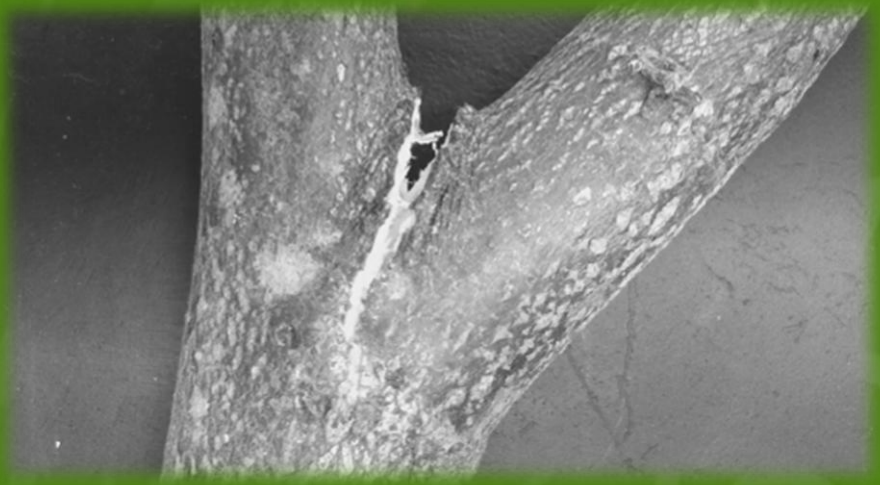
Two modes of fork failure

- Progressive Buckling
- Scissor Action Failure

Progressive Buckling

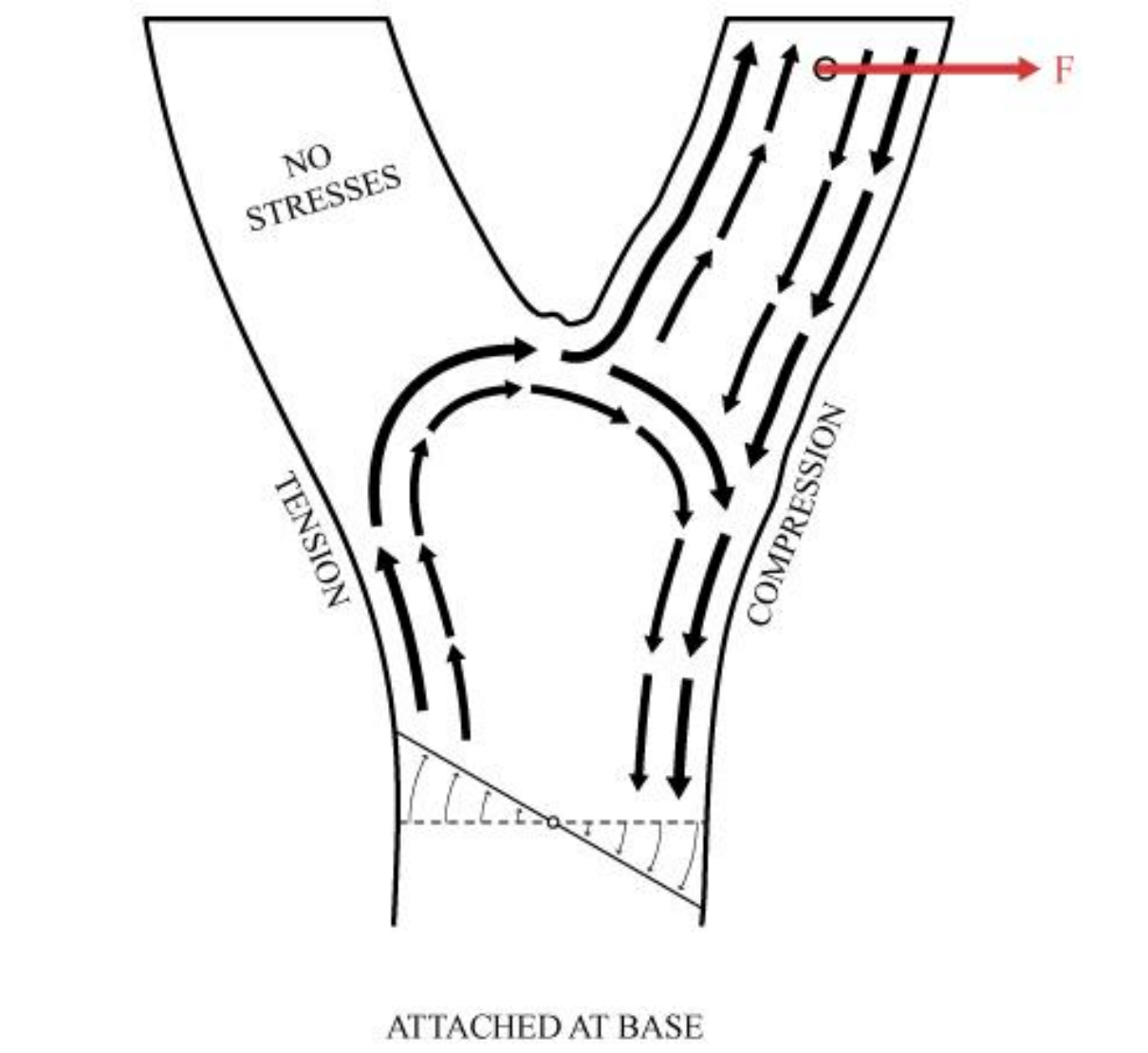
- Compressive yielding can be seen as ripples, starting at the outer edge of the smaller member, and working its way down that member, before a crack occurs at the apex of the fork

Scissor Action Failure

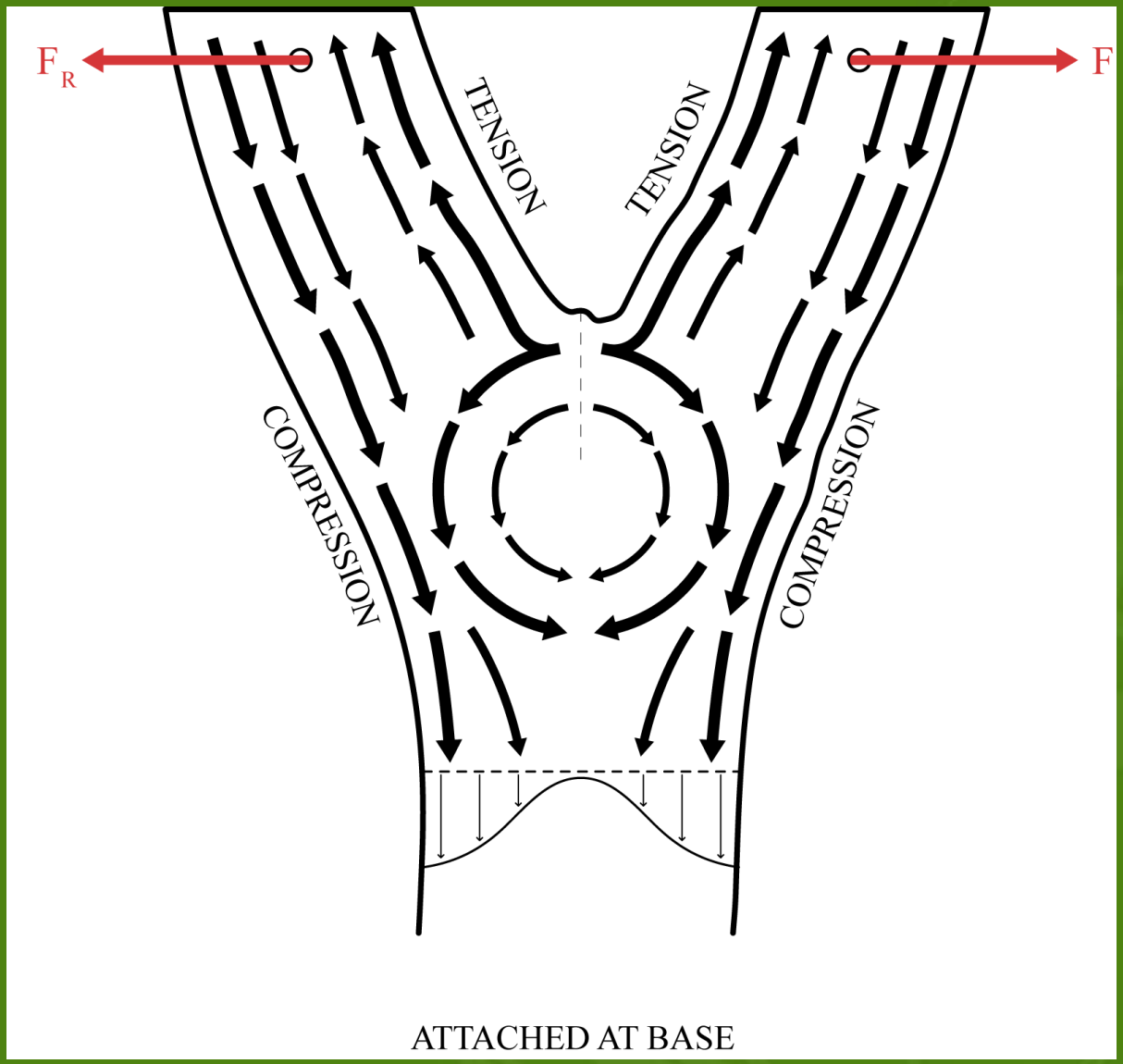


- No compressive yielding is seen on the outer edge of either member
- This mode of failure occurs where the two fork members are more equal in diameter

Force flow – single pull

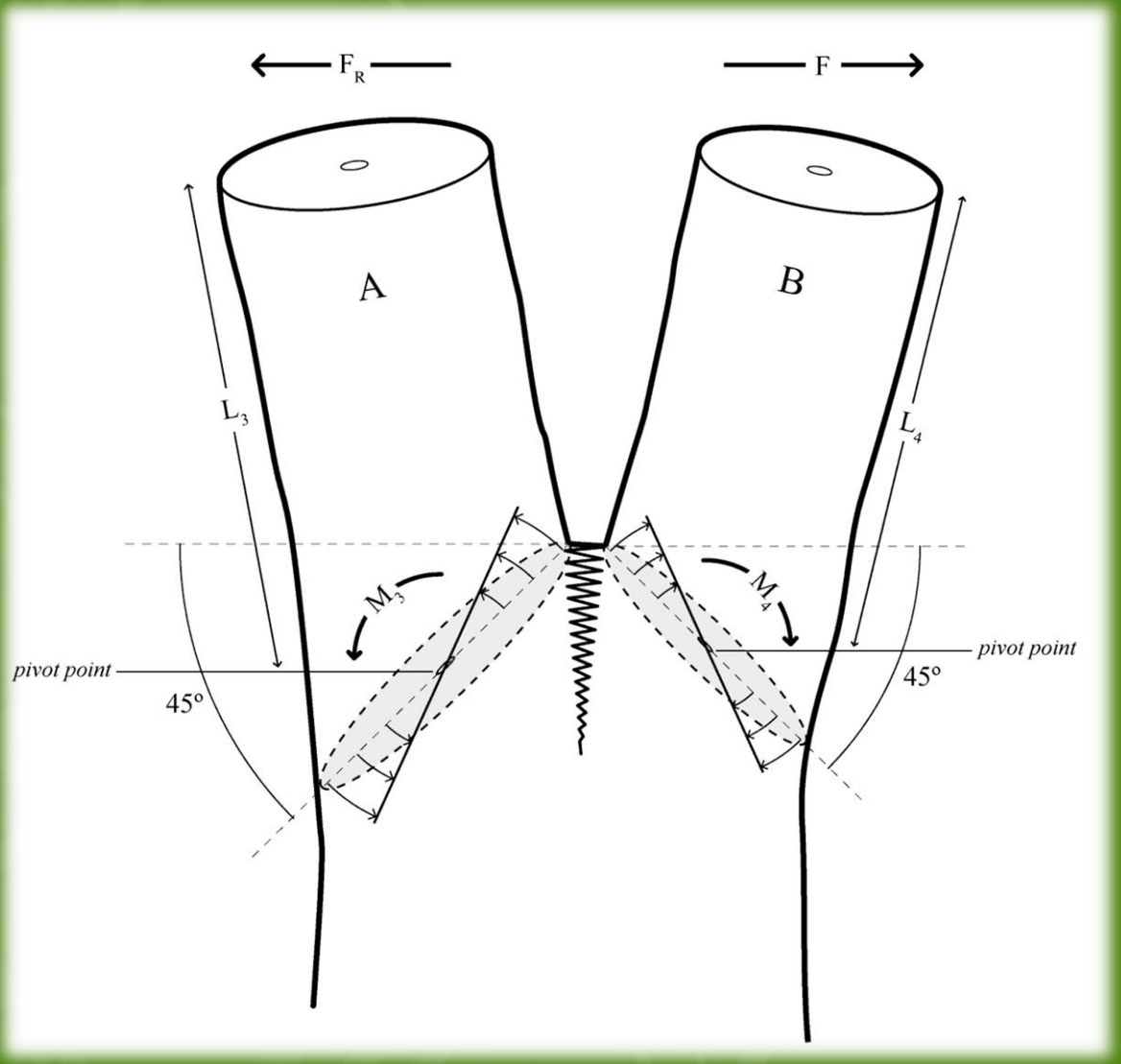


Force flow – both pulled



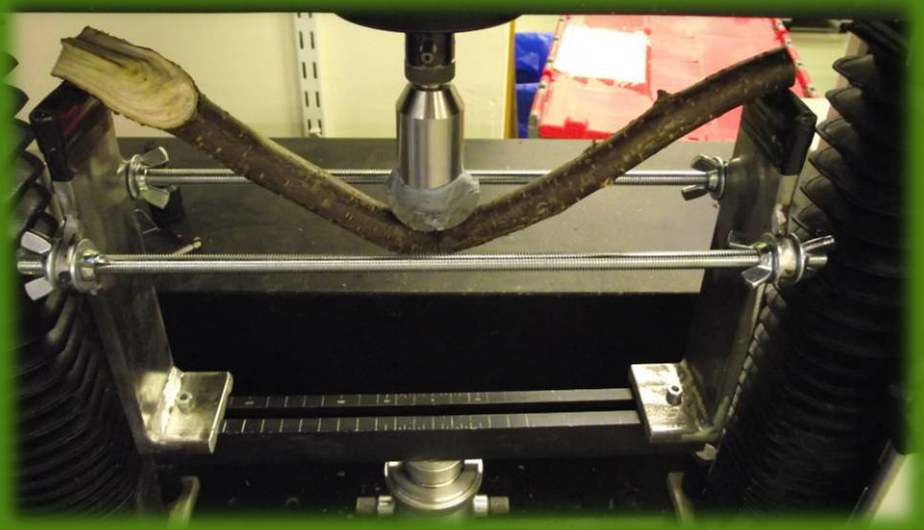
Swirling Forces - Evidence

Modelling Bending Stresses



Deeper pivot point - Evidence

Forks compared with branches

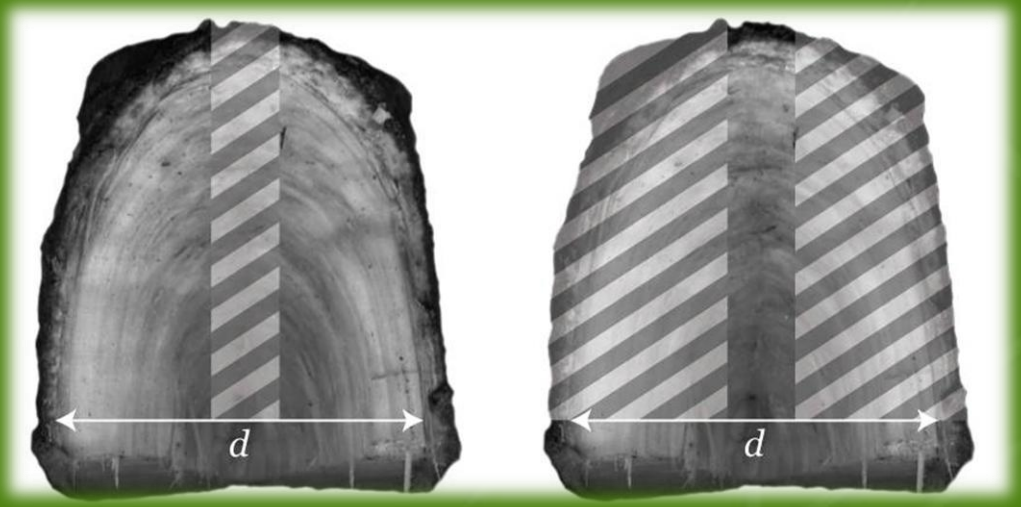


Range of fork strength to branch strength

46% ↔ 68% ↔ 94%

Avg.

Components of a fork



- Drilling out the centre 20% (by width) of the fork attachment reduced strength by c. 36%
- Sawing out the two outer edges of the fork attachment, to leave only 20% of the attachment, reduced strength by c. 52%

Wild Conjecture

- Tree forks can adapt to their on-going stresses in a number of ways:

REMODELLING:

- Increased density of wood
- Change in proportion of each cell type
- Increase in grain reorientation
- Use of whorled grain and ripple grain
- The addition of ribs and ridges
- Occluding an inclusion

Wild Conjecture II

- Open-topped bark inclusions may be more of a problem than occluded ones
  - Peak tensile stresses act at the top of the fork when the arising members sway in opposite directions
  - Open-topped bark inclusions may assist in both the initiation and propagation of a crack at the fork apex – called a ‘singularity’

Wild Conjecture III

- It may be possible to measure and then compare the strength of a union with the arising members
  - Measure the fork attachment parameters
  - Measure the diameters (perpendicular and in-line) of the arising members
  - Estimate strength loss

The allometry of forks

The allometry of forks

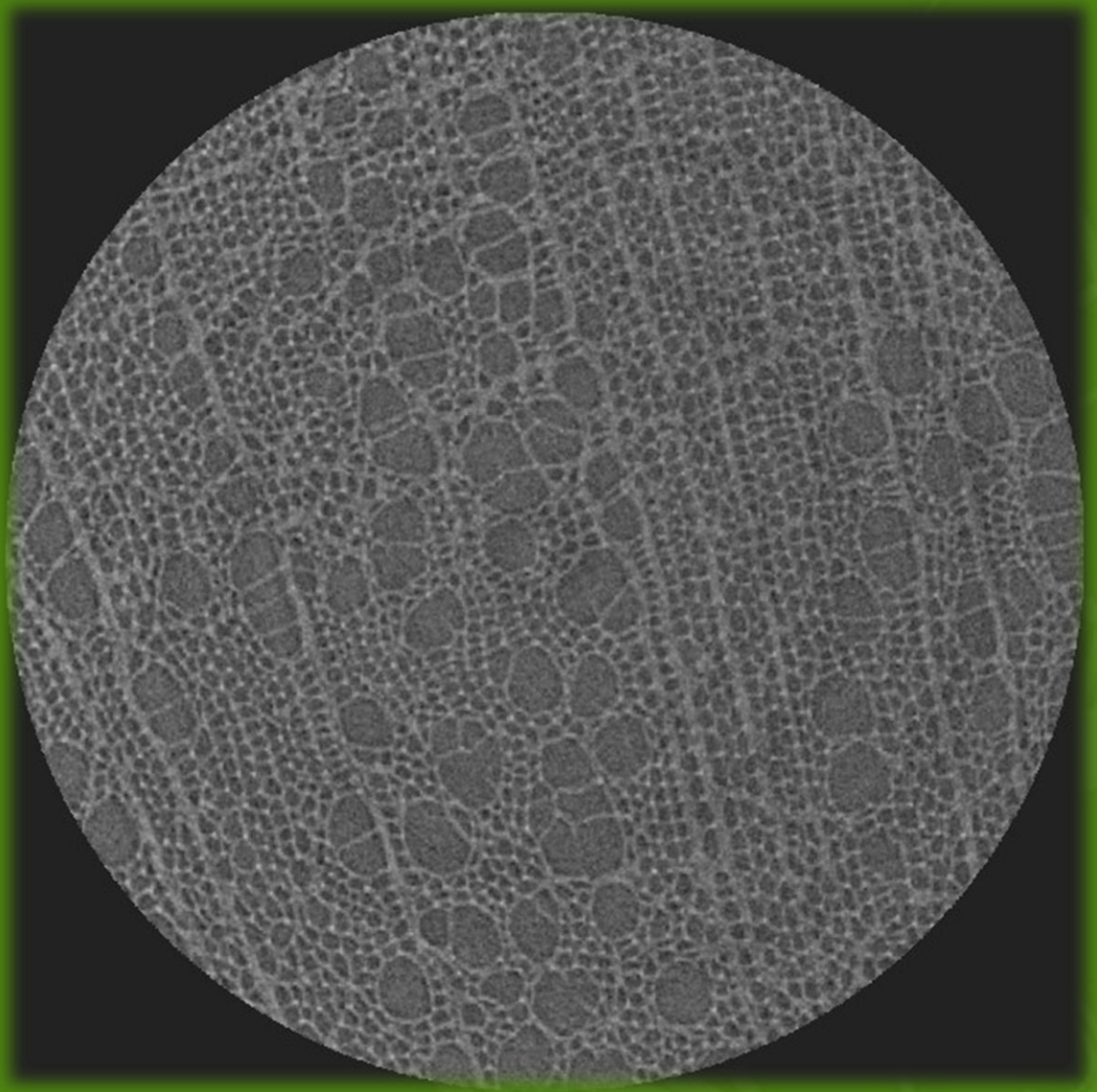
Further research

- Mechanical modelling to be advanced by carrying out Finite Element Analysis of models of tree forks
- Pulling tests to be carried out upon many forks with included bark
- On-going anatomy studies hope to add more detail on the nature of the wood within a fork

Fork internal anatomy

- Normal histological approaches won't yield useful data because of the twisting nature of the wood's grain at forks
- Fortunately, the University of Manchester has some excellent CT scanning facilities, along with an environmental electron microscope, which are ideal for analysing 3D shapes

CT Scans



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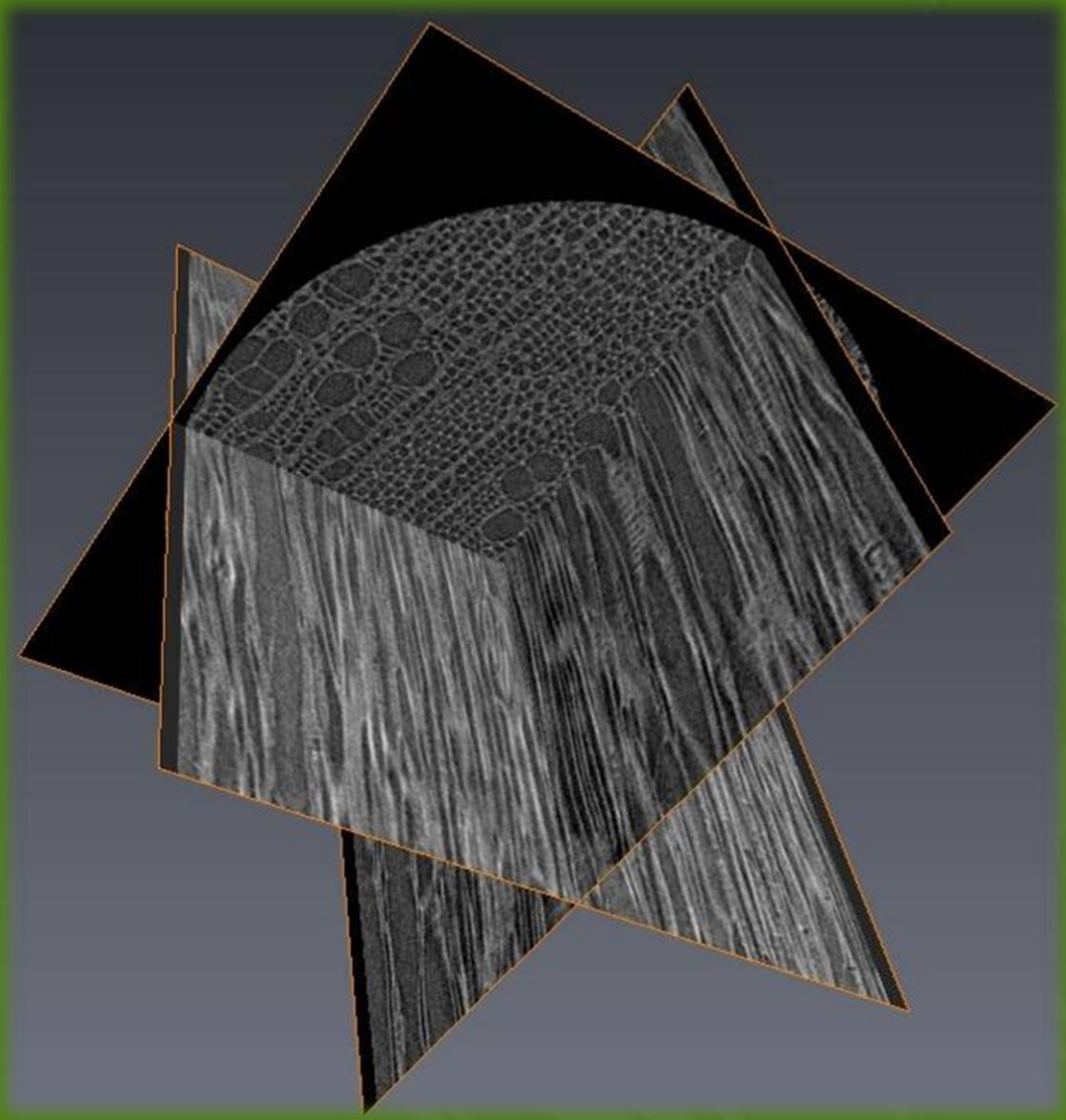
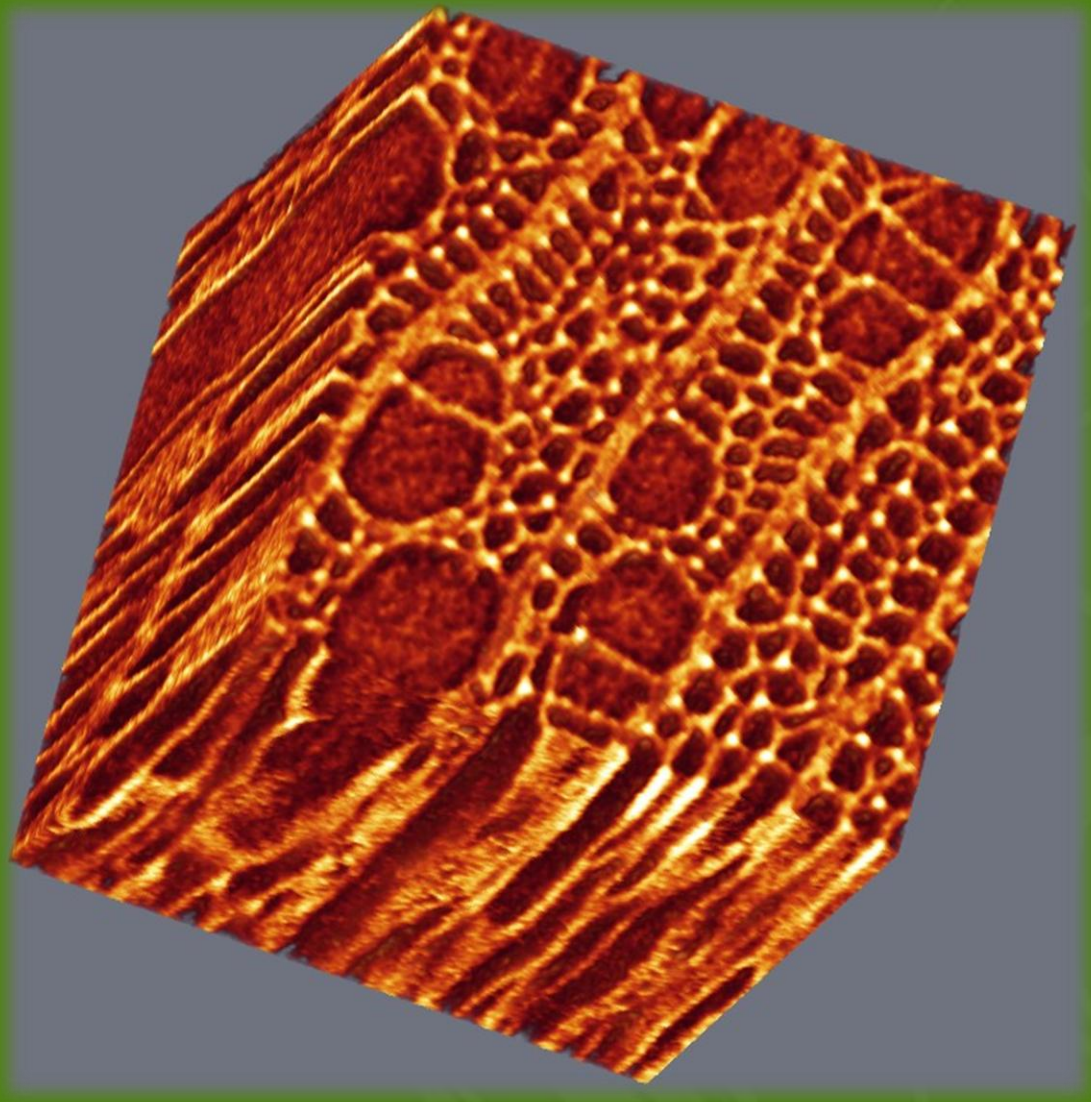
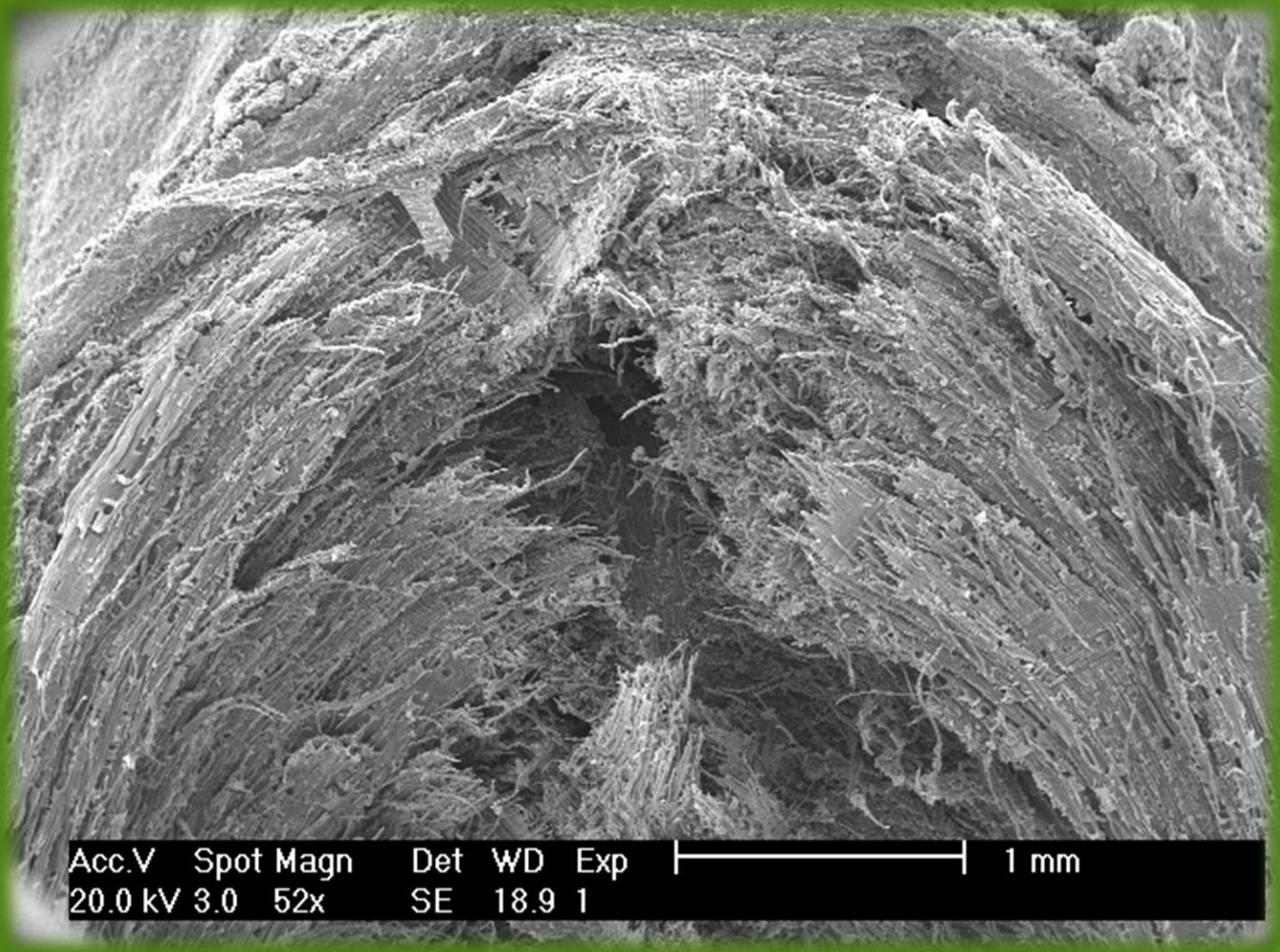


CT Scans



ESEM of Fracture Surface



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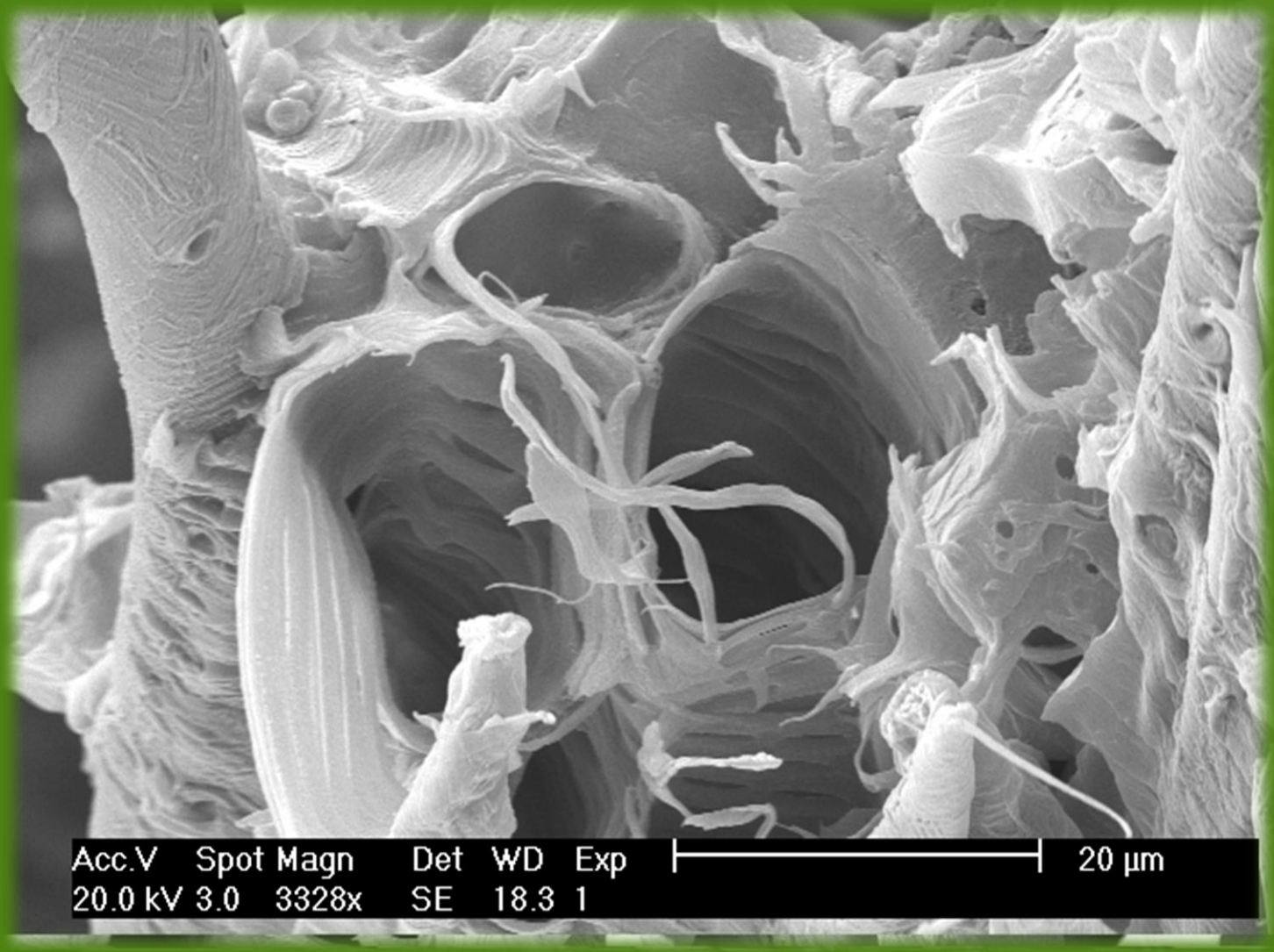

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