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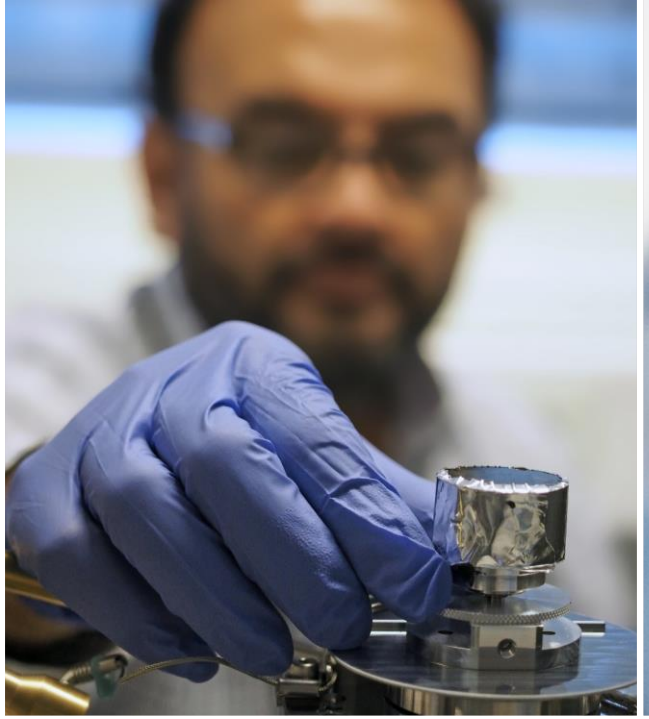
# BIOCOMPOSITES

Gary Chinga Carrasco

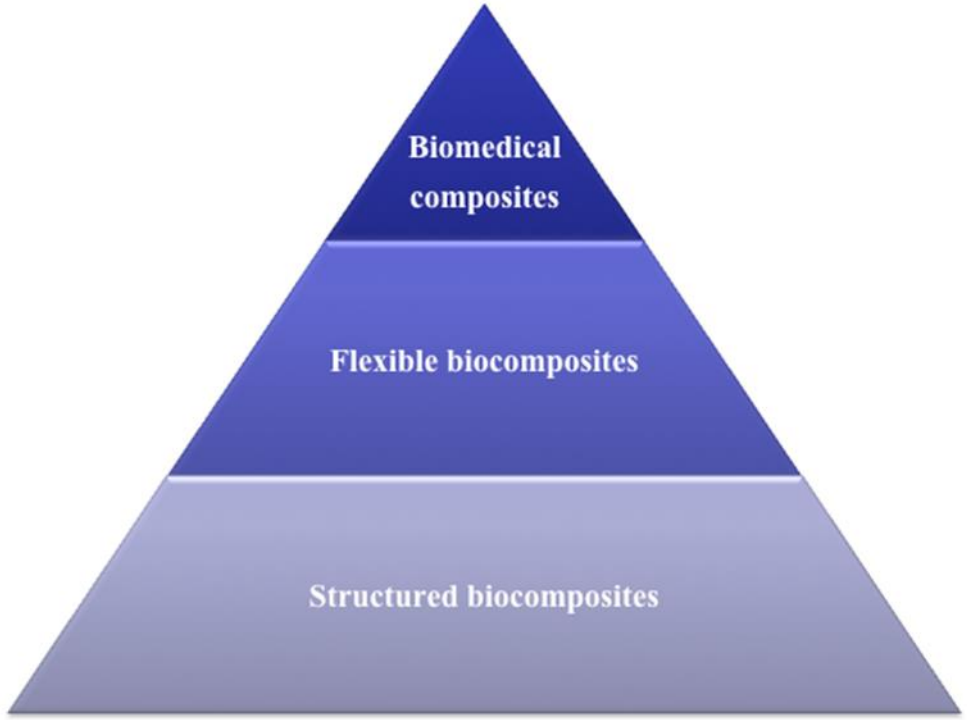
October 25th, 2017

RISE PFI AS




# Biocomposites

- The market for biocomposites continues to grow, and is expected to have a significant share in various industrial applications, including;
  - Bio-applications
  - Flexible biocomposites
  - Structured biocomposites




- There is a need for biobased solutions!



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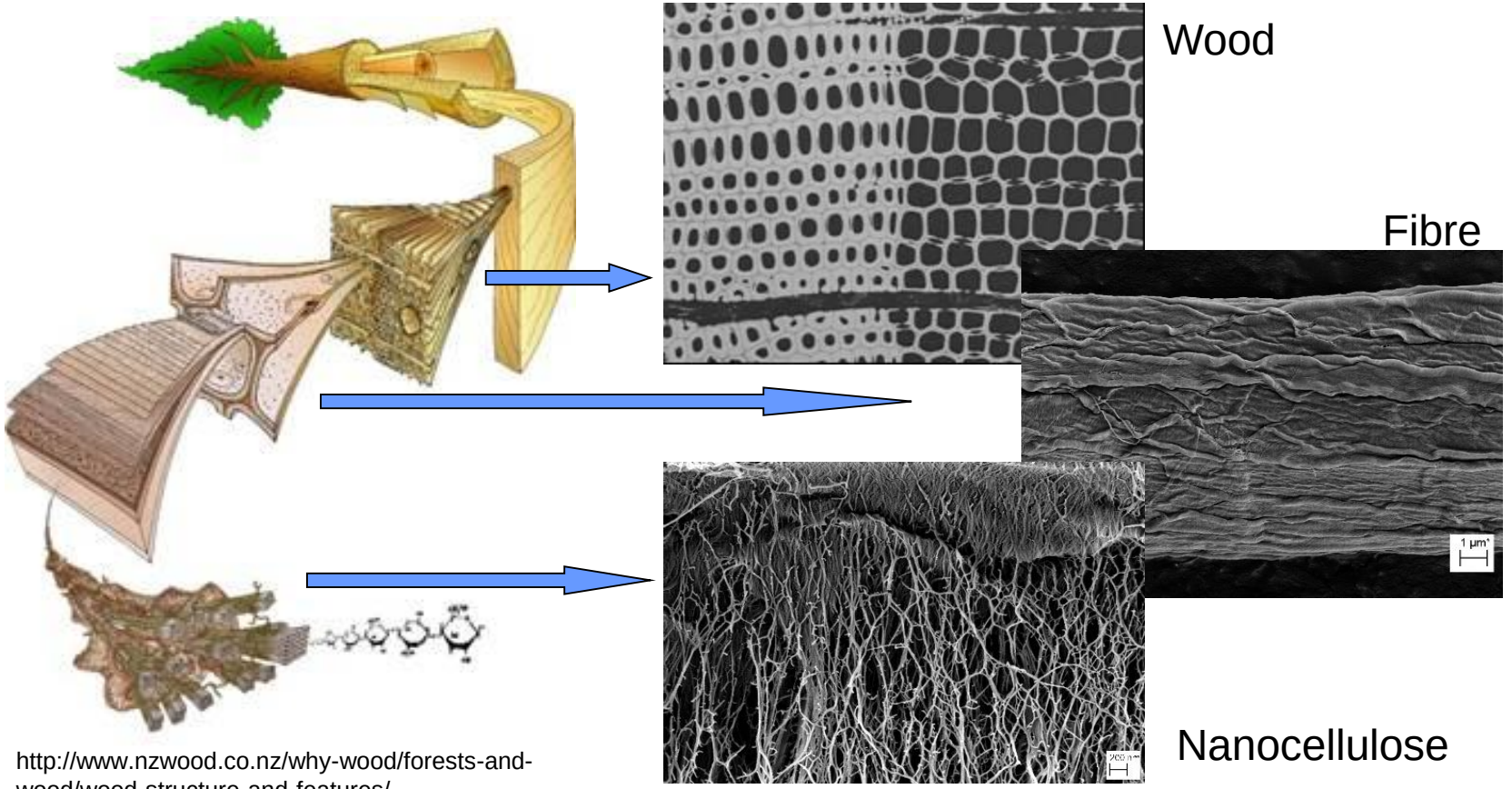
# Biocomposites

- The Biocomposite group at RISE PFI works with two main routes for biobased solutions:
  1. Fibre and nanocellulose




http://www.nzwood.co.nz/why-wood/forests-and-wood/wood-structure-and-features/



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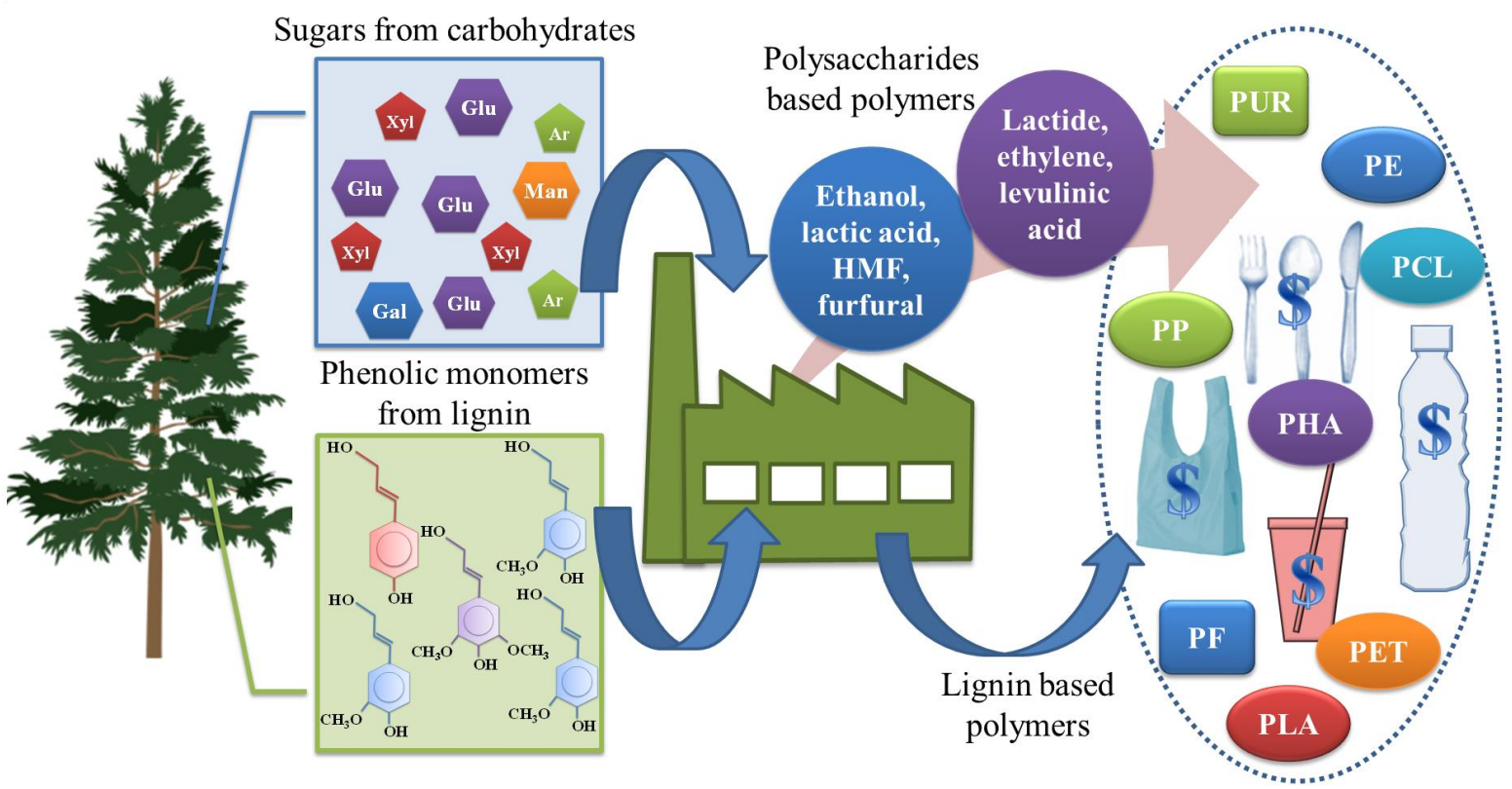
# Biocomposites

- The Biocomposite group at RISE PFI works with two main routes for biobased solutions:
  1. Fibre and nanocellulose
  2. Bioplastics






Brodin, Vallejos, Tanase, Area, Chinga-Carrasco. Lignocellulosics as sustainable resources for production of bioplastics – a review. J. Cleaner Production, 162, 646-664, 2017.

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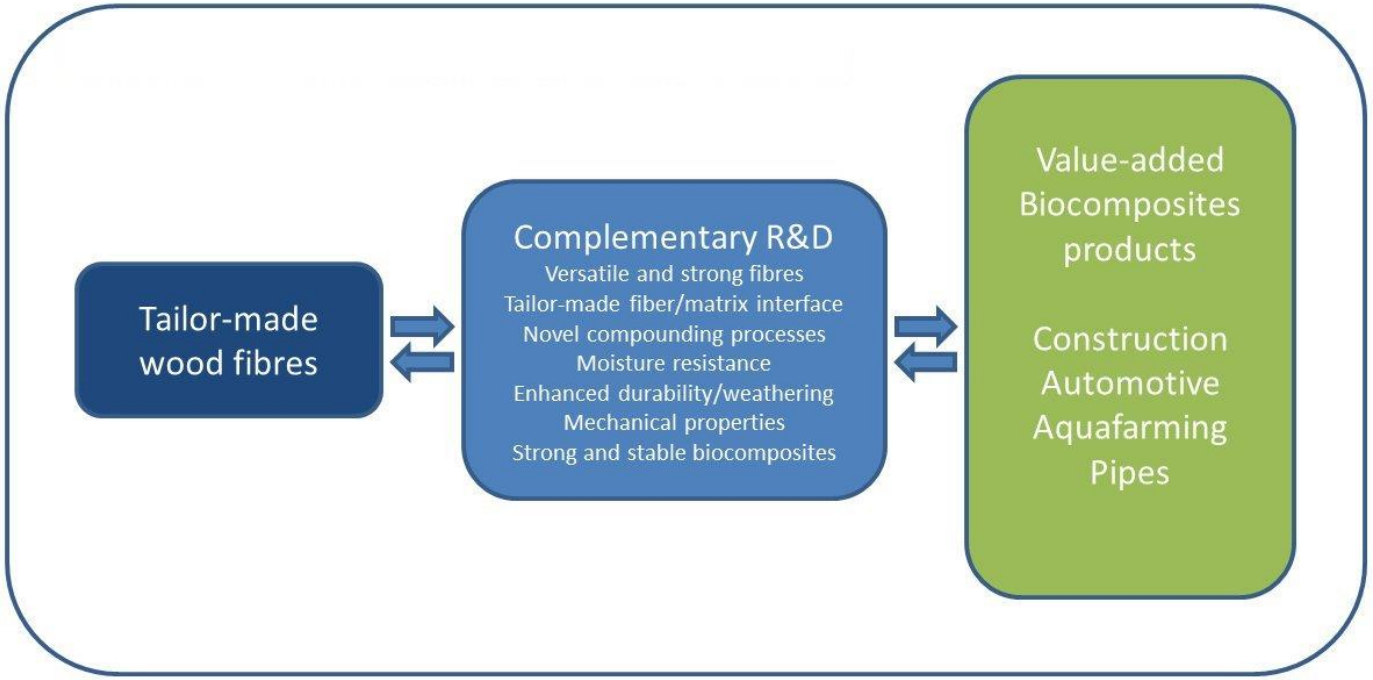
# Structural biocomposites

- **FiberComp** – High performance wood fiber composite materials
  - Fibre-reinforced biocomposite products
  - User-driven Research based innovation program (BIA)
  - Close cooperation with Norwegian industry and R&D
  - Project period 2015-2018
- **Project owner**: Norske Skog Saugbrugs
- **Biocomposites** for;
  - Automotive
  - Construction
  - Infrastructure




http://www.rise-pfi.no/focus-areas/biocomposites/fibercomp/



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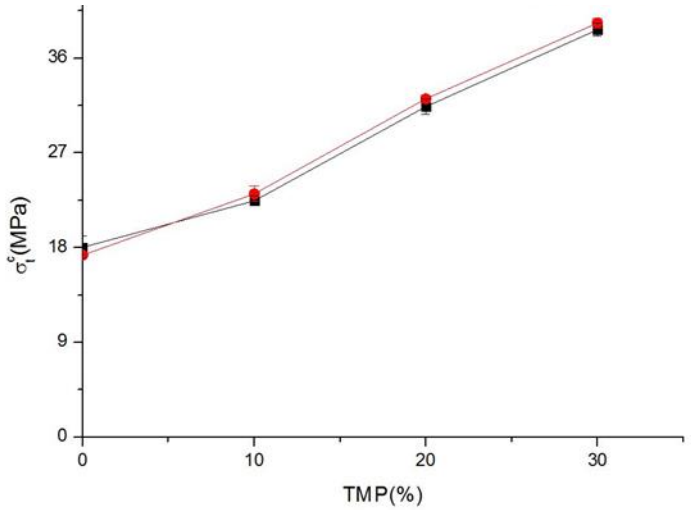
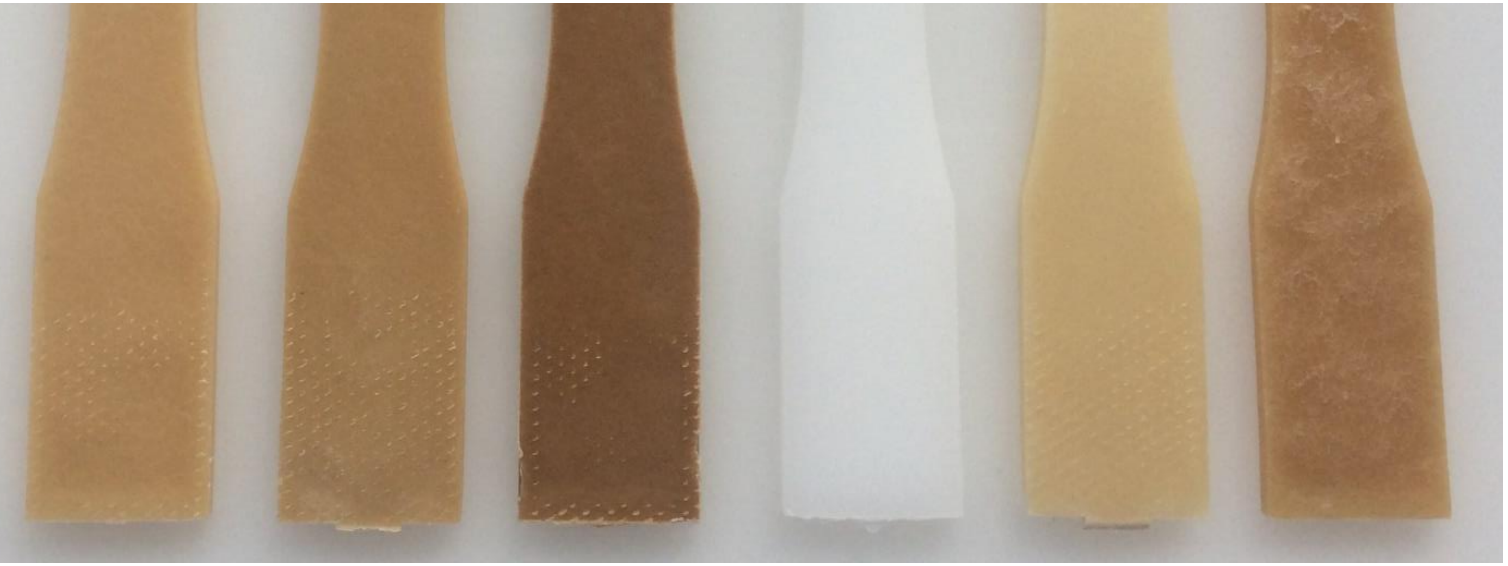
# Structural biocomposites

- **Benefits**
  - Stronger biocomposites
  - Biodegradable or durable, depending on the application
  - Competitive price
  - Improved environmental performance

Biobased Polyethylene (BioPE) with Thermomechanical pulp (TMP) fibres



| BioPE | TMP (w %) | (GPa) | $\varepsilon_{max}$ (%) |
|---|---|---|---|
| BioPE1 | 0 | 1.06 ± 0.03 | 10.59 ± 0.53 |
| | 10 | 1.57 ± 0.04 | 8.09 ± 0.33 |
| | 20 | 2.44 ± 0.08 | 5.98 ± 0.24 |
| | 30 | 3.26 ± 0.06 | 2.90 ± 0.42 |



Tarres et al. Biobased polyethylene reinforced with thermomechanical pulp fibers. To be submitted.

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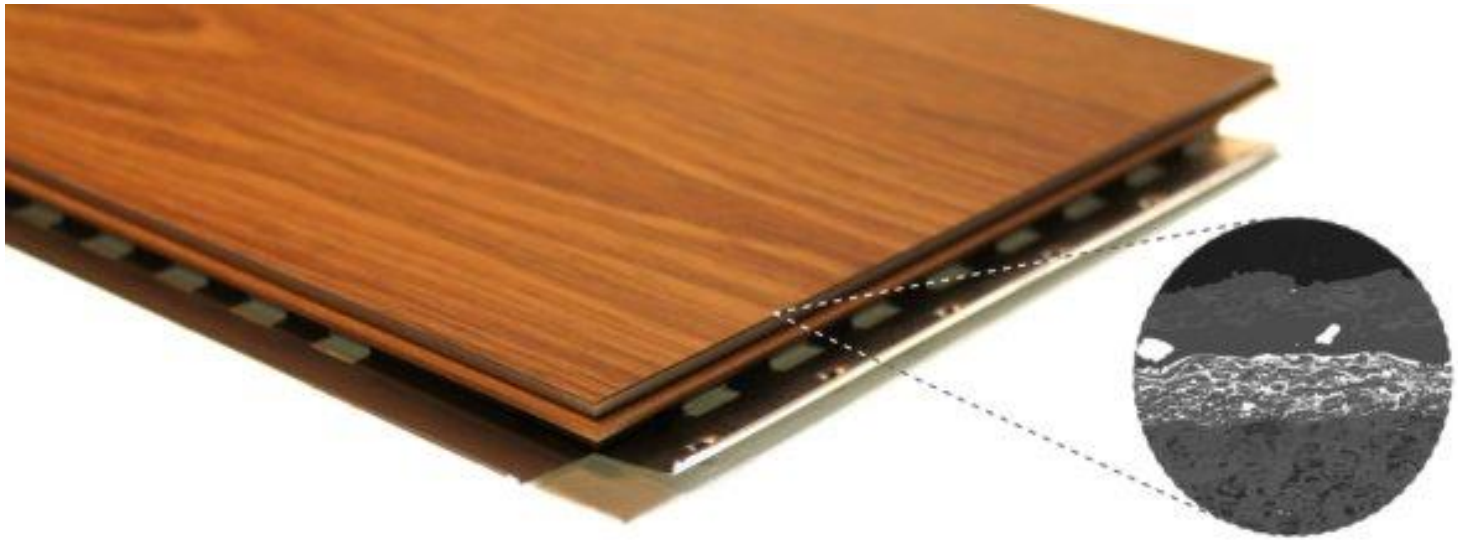
# Flooring solutions

- **ElefantGolv** – New innovative flooring solutions
  - User-driven Research based innovation program (BIA)
  - Close cooperation with Norwegian industry
  - Project period 2013-2017
- **Project owner**: Alloc AS, Lyngdal

- **Biocomposites** for:
  - Flooring
  - Wall panels

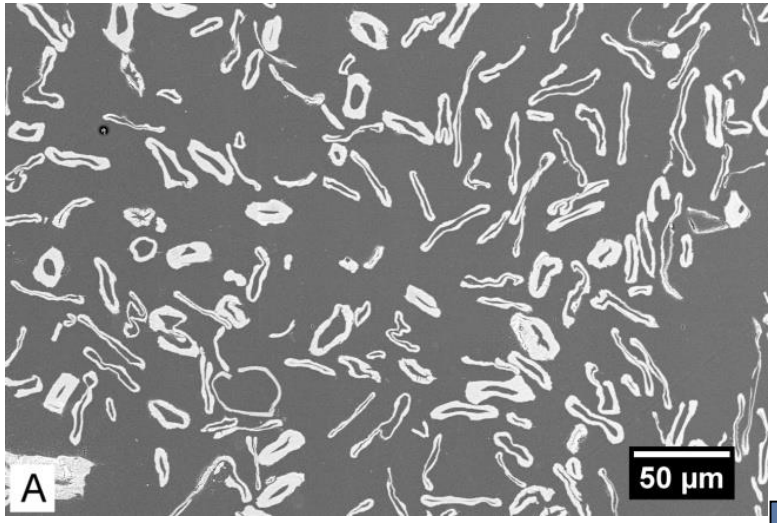
- **Opportunities** for:
  - Wood fibres
  - Biobased resins
  - Recycled paper, side streams

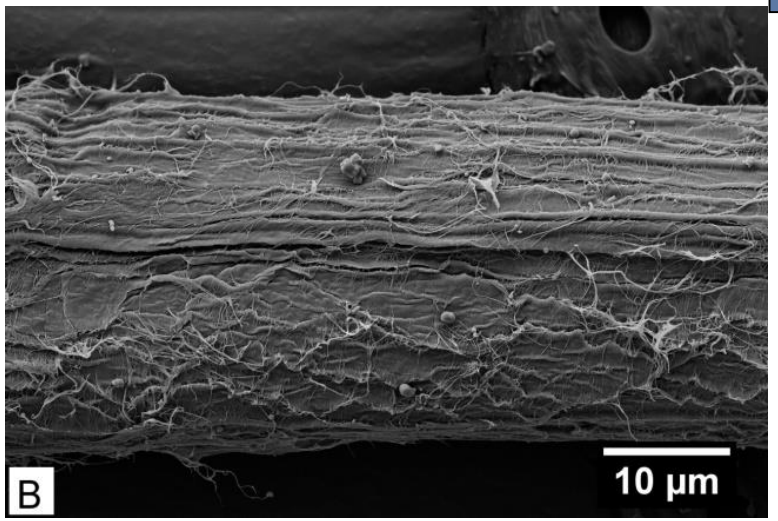


http://www.rise-pfi.no/focus-areas/biocomposites/elefantgulv/

# Nanocellulose production from wood fibres

Cellulose fibres

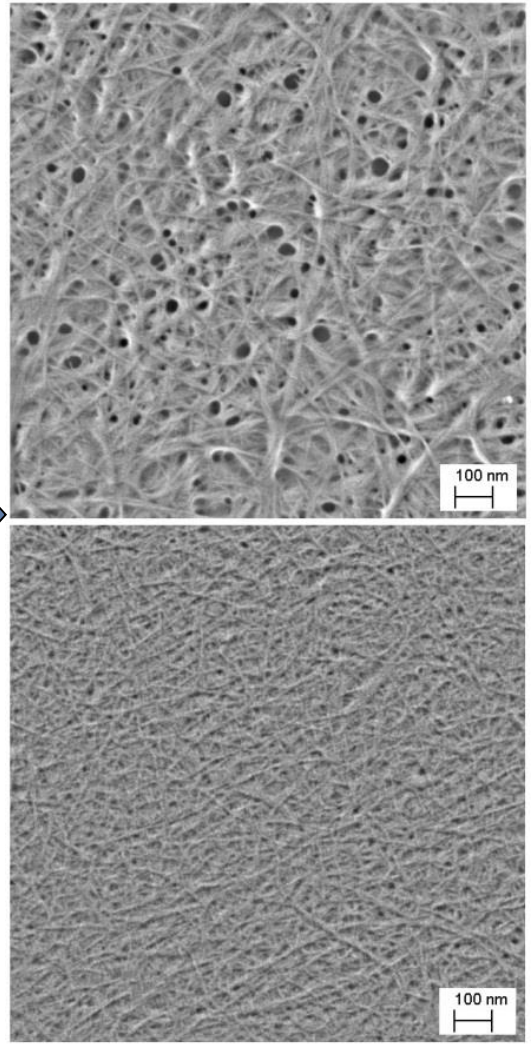



**Nanocellulose production**

•Chemi-mechanical process

Cellulose nanofibrils (CNF)



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# Nanocellulose production

- Several grades of nanocelluloses;
  - Bacterial cellulose
  - **Cellulose nanofibrils (CNF)**
  - Cellulose nanocrystals (CNC)

- Pre-treatments include;
  - Mechanical
  - Chemical
  - Enzymatic

- Production unit;
  - Grinders
  - Homogenizers
  - Fluidizers
  - Extruders

| Nanocellulose | Carboxyl (µmol/g) | Carboxy-methyl (µmol/g) | Aldehyde (µmol/g) | Sulphate half ester (µmol/g) | Intrisic viscosity (ml/g) / DP | Nanofibril diameter (nm) | Nanofibril length (µm) |
|---|---|---|---|---|---|---|---|
| M-CNF[1] | 100 | | | | 620 / 890 | <100 | > 1 |
| E-CNF[2] | 24 | | | | 408/913 | ~20 | >1 |
| T-CNF | 764±60[3] | | 211±60[3] | | 450 / 620[1] | < 20[1] | > 1[1] |
| C-CNF | 58±1[3] | 346 ± 26[3] | | | | < 20[1] | > 1[1] |
| C-P-CNF[4] | 393 | | 1202 | | <80 | < 20 | < 0.2 |
| CNC[1] | | | | 300 | 80 / 90 | < 20 | < 0.2 |

1-4: Literature values



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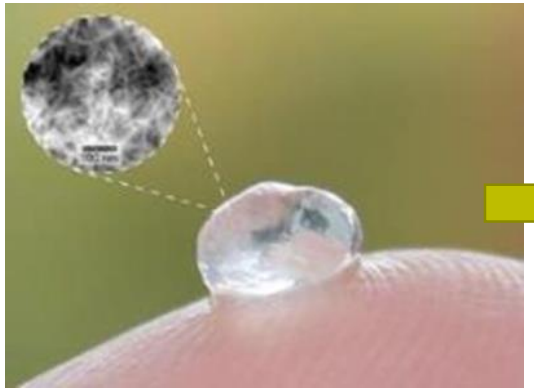
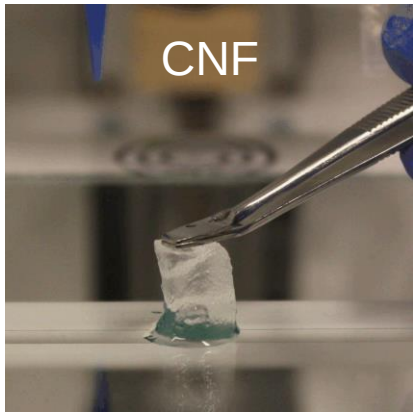
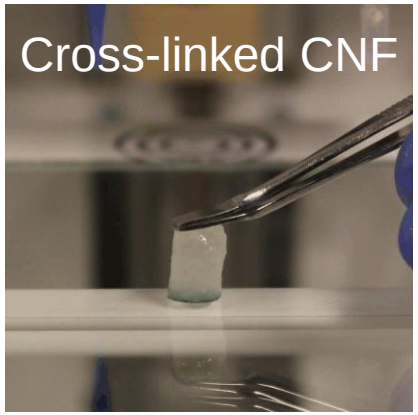
# Wound dressings



- **NanoHeal (2012-2016)**
- **Researcher project**: Nano2021
- **Project owner**: RISE PFI
- **Close cooperation**: NTNU, Institutt for Klinisk og Molekylær Medisin, Hudavdelingen, St.Olavs Hospital

- Development of wound dressing materials;
  - Develop an ultrapure nanocellulose from wood
  - Control the porous structure of wound dressings
  - Clarify the interaction of nanocellulose and wound bacteria
  - Develop wound dressings with adequate mechanical and structural properties
  - Functionalize the wound dressings with printing techniques



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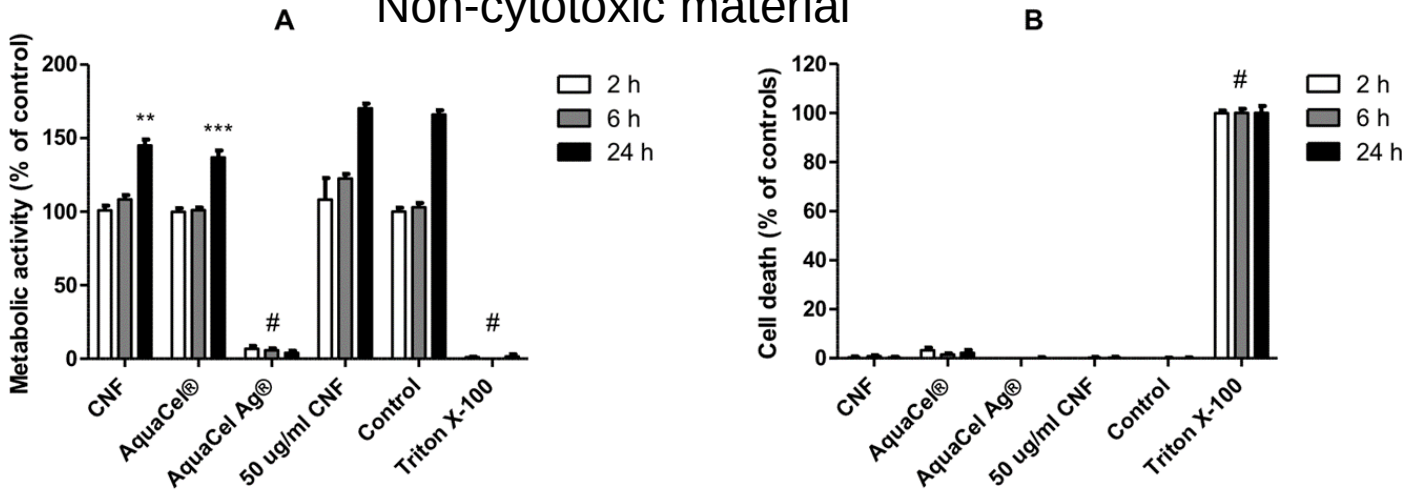
# Wound dressings

- Cytotoxicity and biocompatibility
  - Screening of various nanocelluloses
  - Mechanical and chemical pre-treated
- The assessment of biocompatibility requires direct contact with living tissue
  - Requires ultrapure nanocellulose materials
  - LPS levels lower than 100 endotoxin units/g

Non-cytotoxic material




- A protocol was implemented based on TEMPO-mediated oxidation
- Considerable reduction of lipopolysaccharide content (LPS)
  - <50 endotoxin units/gram nanocellulose
- Non-cytotoxic



Nordli, H.R., Chinga-Carrasco, G., Rokstad, A.M., Pukstad, B. Carbohydrate Polymers 150: 65–73 (2016).

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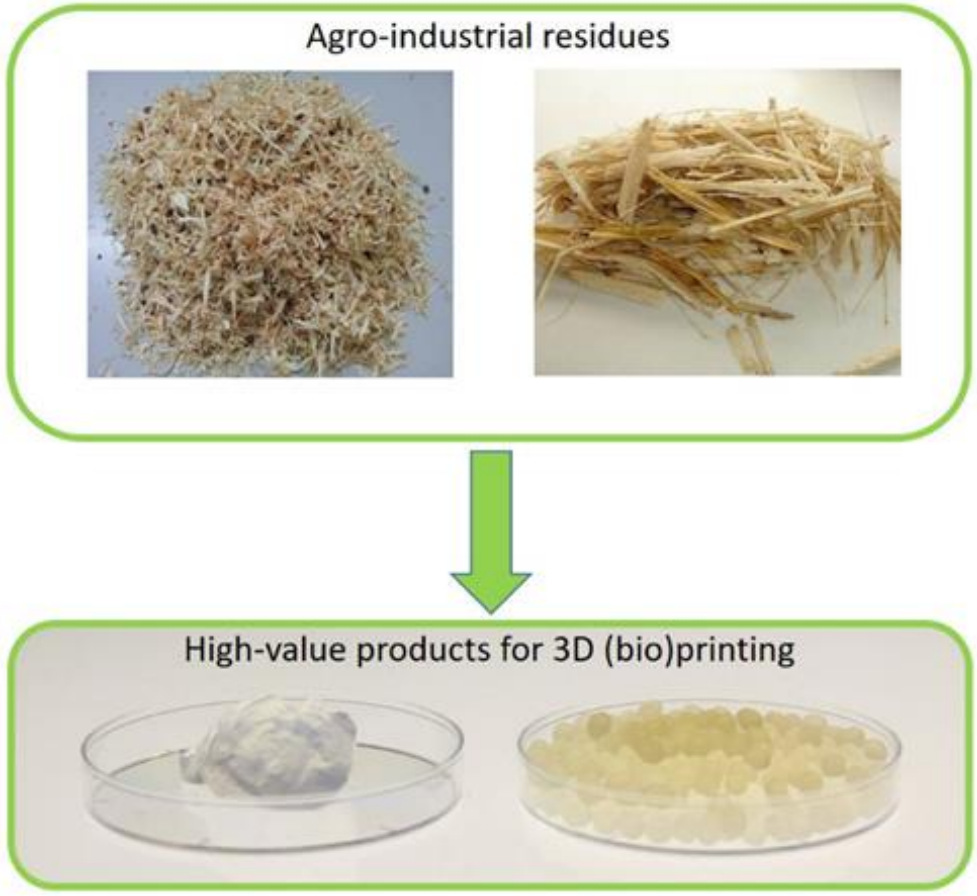
# 3D Printing

- **ValBio-3D**:  Valorization of residual biomass for advanced 3D materials
- A multi-disciplinary project between European and South American key R&D groups and industry.
- **Researcher project**: BIONÆR
- **Project period**: 2017-2019
- **Project owner in Norway**: RISE PFI

- **Focus on:**
  - Bioplastic production
  - Nanocellulose from agro-industrial waste
  - Biocomposites
  - 3D (bio)printing




http://www.rise-pfi.no/focus-areas/biocomposites/valbio-3d/



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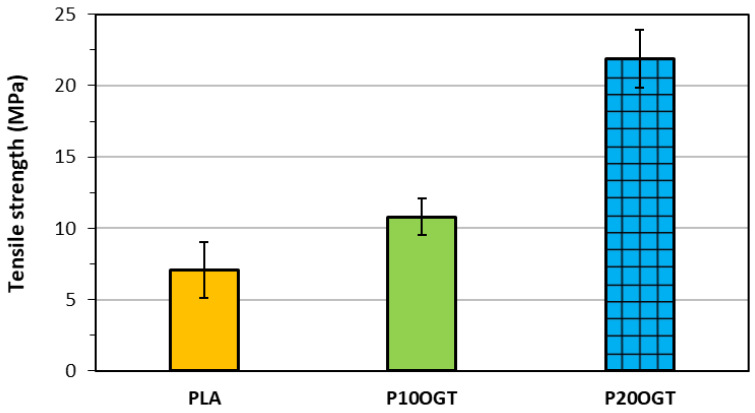
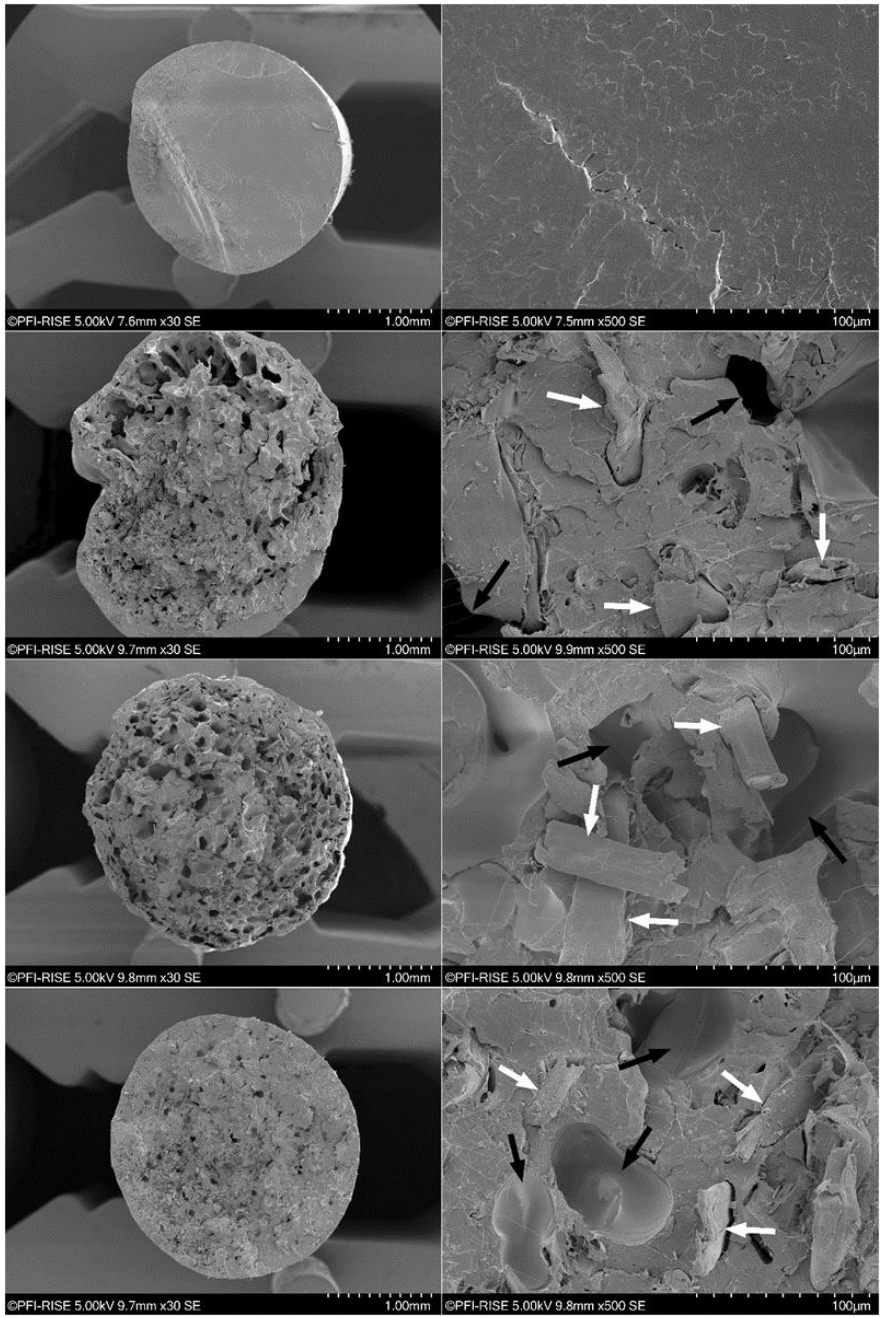
# 3D Printing

- Filaments for fused deposition modelling (FDM):
  - PLA and TMP fibres




Filgueira et al. Enzymatic-assisted modification of TMP fibres for improving the interfacial adhesion with PLA for 3D printing: ACS Sustainable Chemistry & Engineering, 2017.

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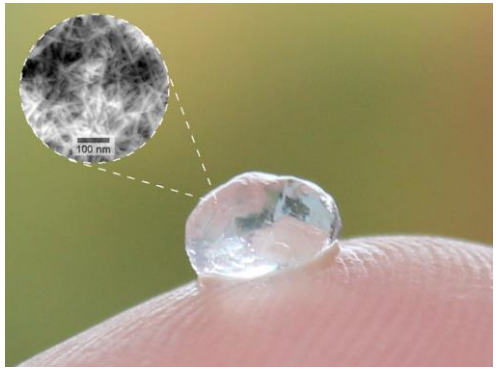
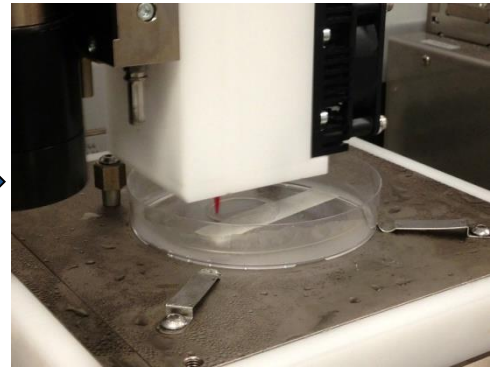
# 3D Bioprinting

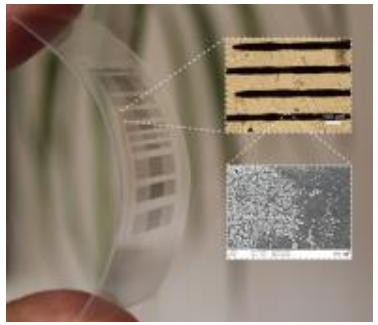
- 3D printing of nanocellulose
  - Customized wound dressings
  - Scaffolds



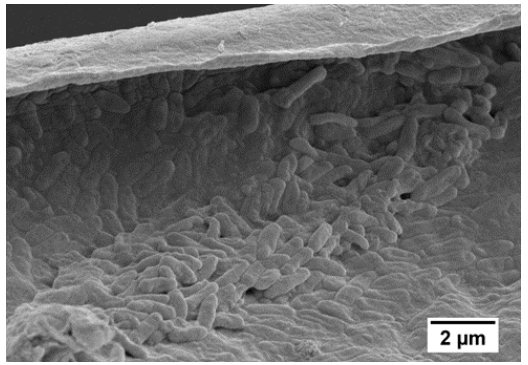

Ultrapure nanocellulose



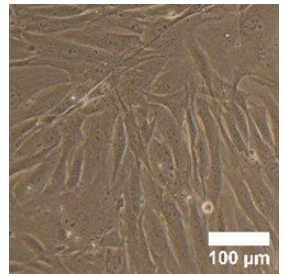
3D bioprinting

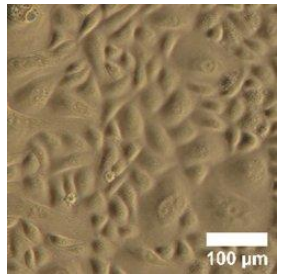


Customized Wound dressing

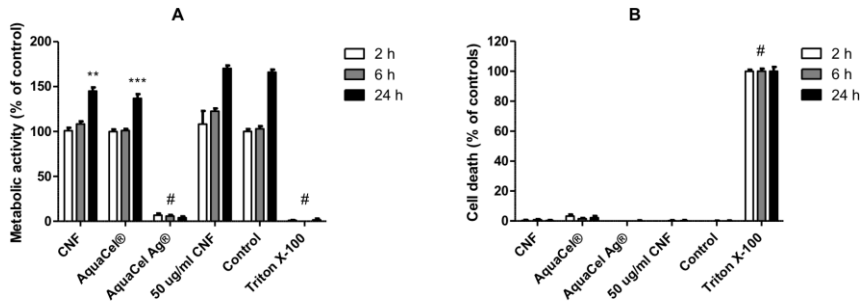



Microbiological




Bio-testing




No cytotoxicity



Rees et al. BioMed Research International. Article ID 925757; Jack et al. (2017). Carbohydrate Polymers 157, 1955–1962; Nordli et al. (2016). Carbohydrate polymers 150: 65–73;

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# Biocomposites

- The group offers:
  - New initiatives in the development of biobased materials
  - Application of bioplastics and wood fibres with potential to replace fossil-based plastics
  - Tailoring of biobased material properties – biodegradable or durable
  - New additive manufacturing technology
  - Close cooperation with Norwegian and European industry
  - Extensive experience with private and public funded projects

- **Join us in the development of the next generation biobased materials!**

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# THANK YOU

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