

EPFL



Fungal Factories for Materials

Tiffany Abitbol

May 16, 2024

Sustainable Materials?

Dictionary

Definitions from [Oxford Languages](#) · [Learn more](#)



sustainable

/səˈsteɪnəbl/

adjective

adjective: **sustainable**

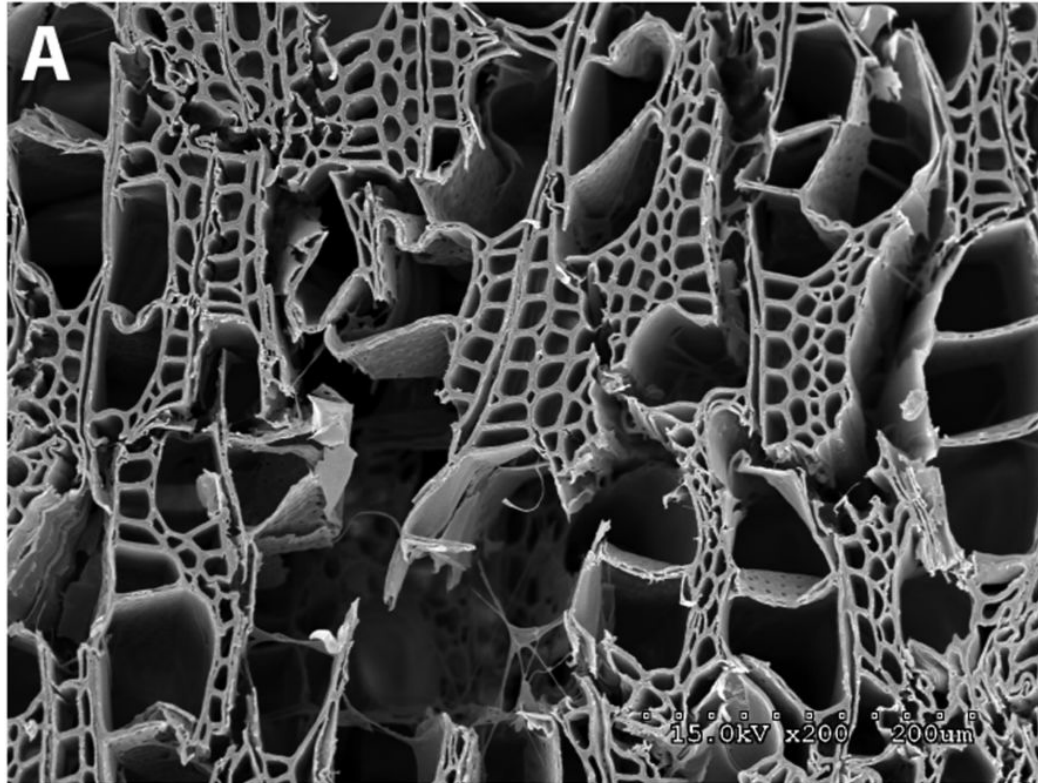
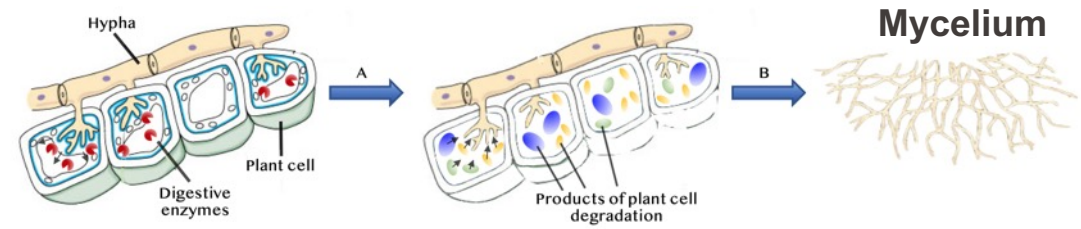
1. able to be maintained at a certain rate or level.
"sustainable economic growth"
 - conserving an ecological balance by avoiding depletion of natural resources.
"our fundamental commitment to sustainable development"
2. able to be upheld or defended.
"sustainable definitions of good educational practice"

Use over time for: sustainable

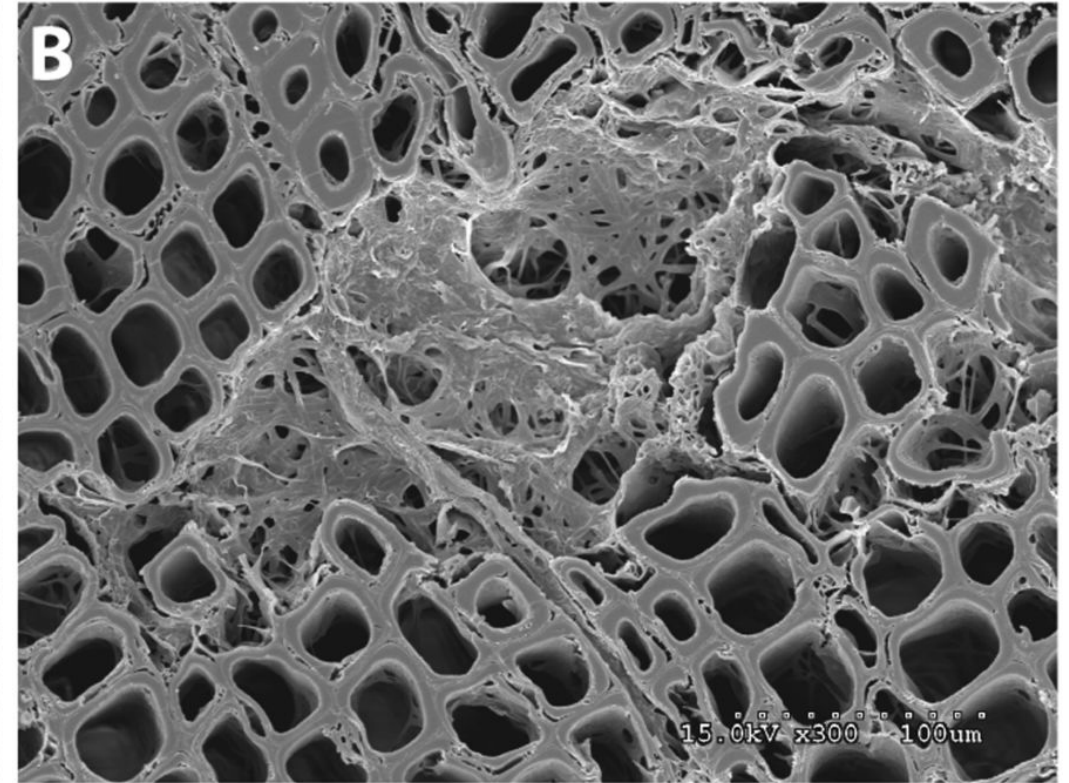


- Materials from renewable resources
- Materials from waste streams
- Biodegradable

Wood decaying fungi



(A) *B. botryosum* on aspen wood with vessel, fiber, and parenchyma cell walls degraded. Mycelia are visible growing through the voids.

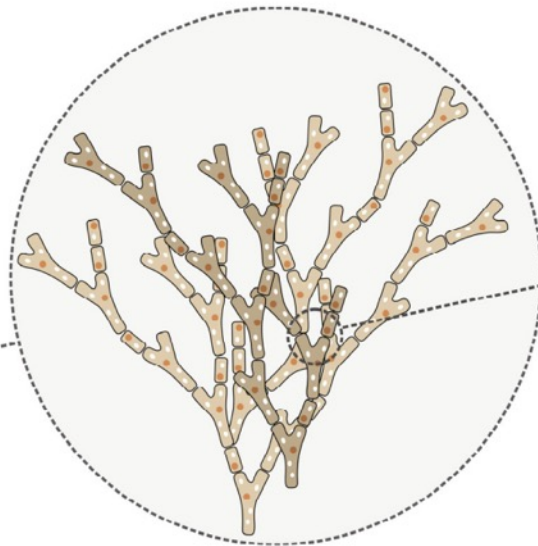


(B) *J. argillacea* on pine showing an area where the fungus has caused a localized simultaneous decay of the cells. Residual cell wall material and mycelia fill the degraded zone.

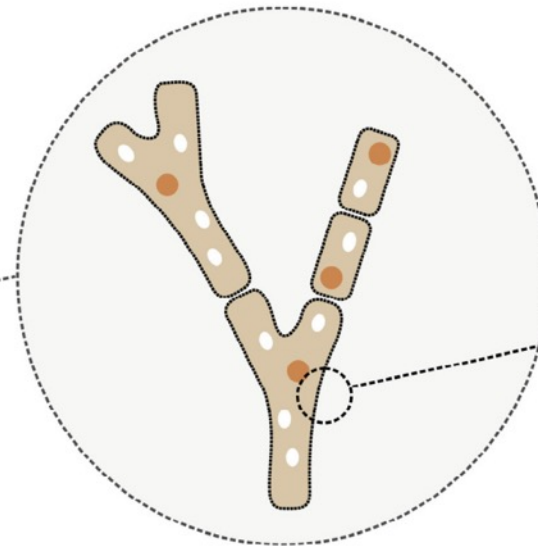
Mycelium



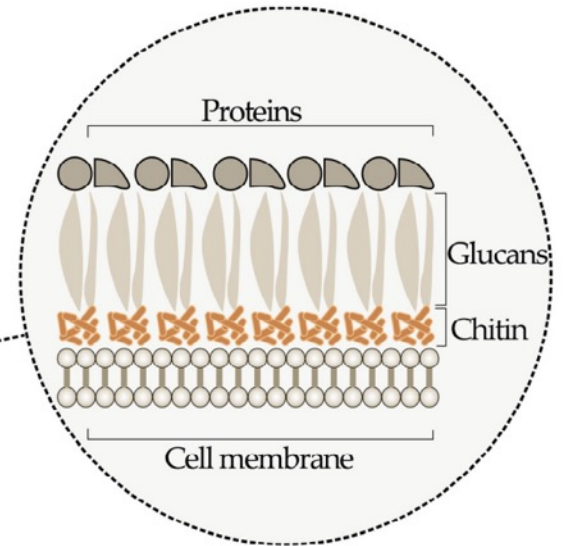
Mushroom



Mycelium



Hyphae



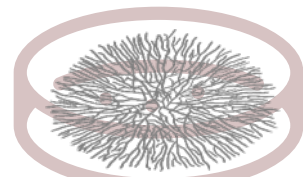
Cell Wall

Fungi for materials



Attias et al., Journal of cleaner production 246 (2019).

Solid Fermentation: Materials grown to shape



fungi



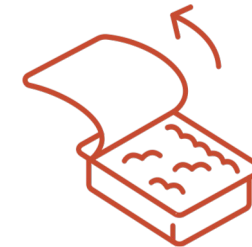
solid nutrition



MATERIALS



mycelium composites



pure mycelium



“MyForest Foods” by Ecovative
Bacon in just 9 days



MycoWorks × Hermès



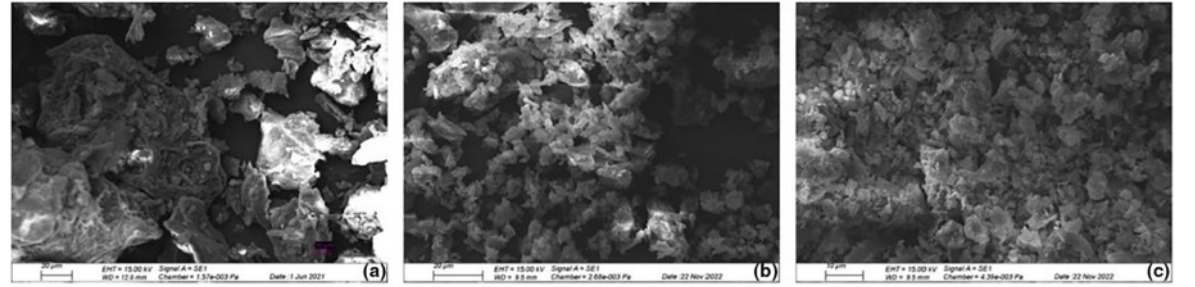
Bolt Threads × Adidas

Food waste is converted to new food:



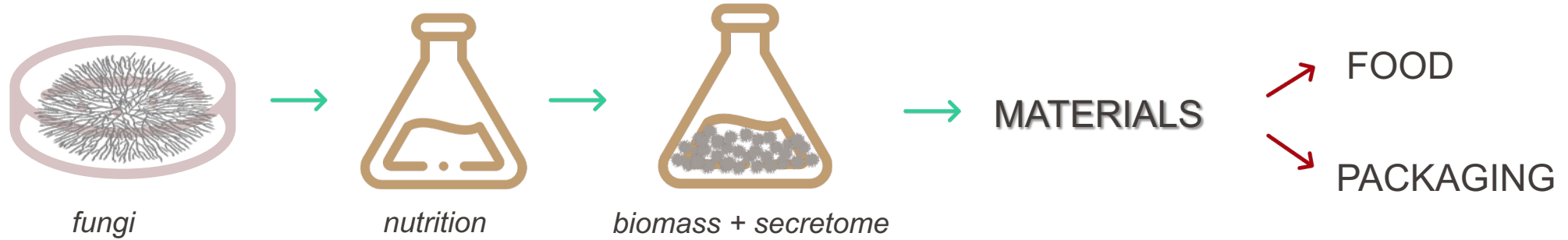
From EU "Smart Protein" project (2020).

Upcycling cocoa pod husks into a fiber & protein-rich ingredient:

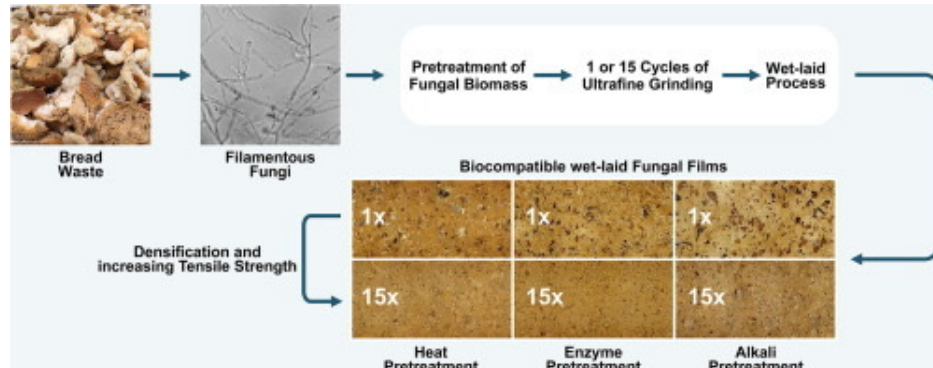


Bickel Haase et al., Food Science & Nutrition 12 (2024).

Submerged Fermentation:

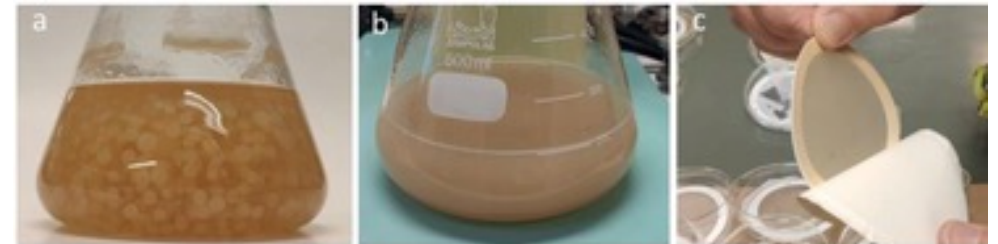


Wet-laid sheets from bread waste:



Köhnlein et al., Materials & Design 216 (2022).

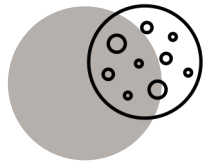
Packaging-relevant films from nanocellulose:



Attias & Abitbol, et al., Advanced Sustainable Systems 5 (2021).

Our approach to mycelium materials

Nature



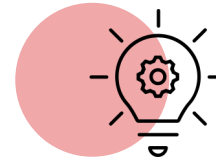
Species

Nurture



Adaptive growth

Nature
vs.
Nurture



Materials



**Adaptive growth
for materials
science relevant
outcomes**

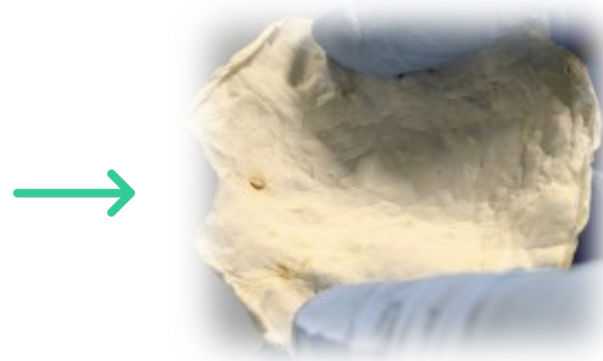
- Encompasses all aspects encoded in genetic script

- Encompasses all aspects of growth environment

- Leveraging nature and nurture toward new materials

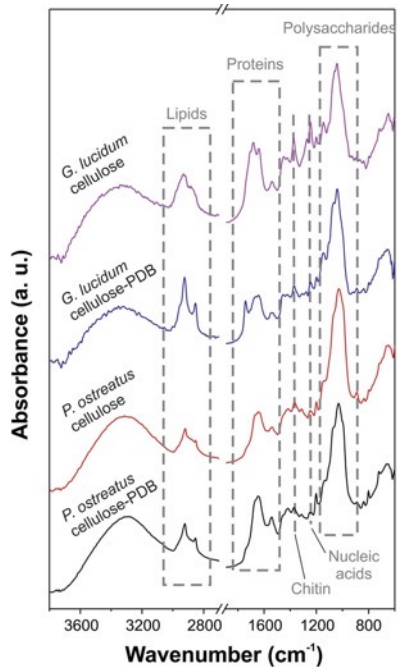
Inspiration

- Pure mycelium mats by solid fermentation
- Compared growth on a complex vs. simple nutrition

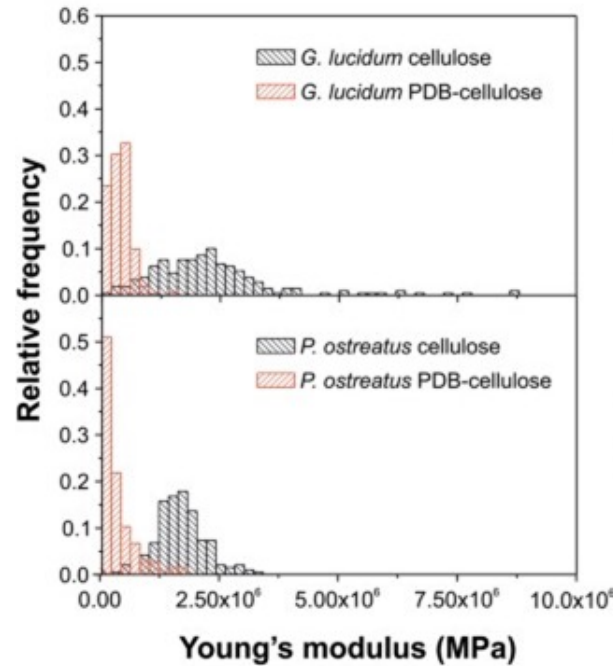


Effects of diet on composition & properties of obtained material?

Composition



Properties



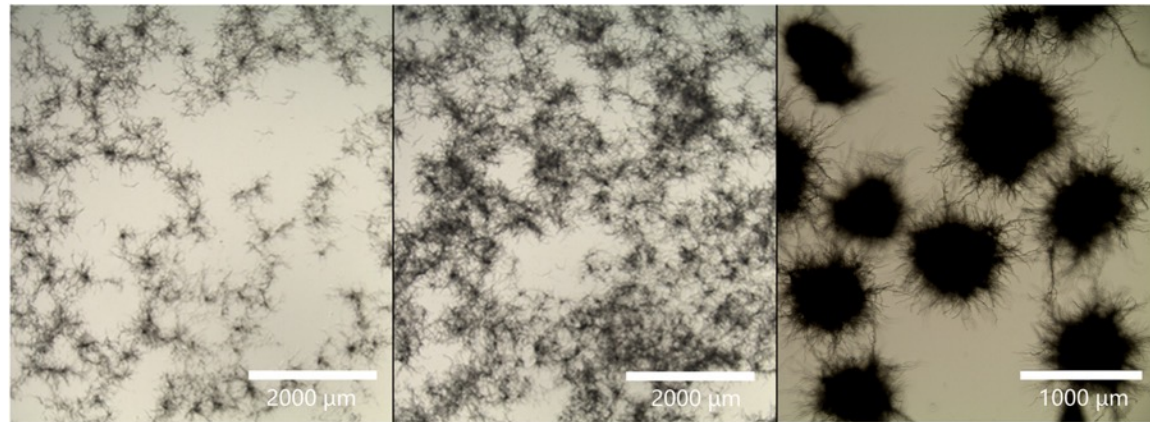
On complex diet:

- More stiff components
- Stiffer

On simple diet:

- More soft components
- Less stiff

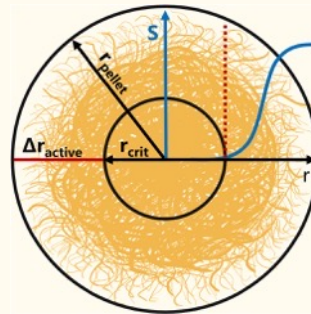
Basics of mycelium growth by submerged fermentation



dispersed mycelium

clumps

pellets



Growth time (days)

After designated growth time

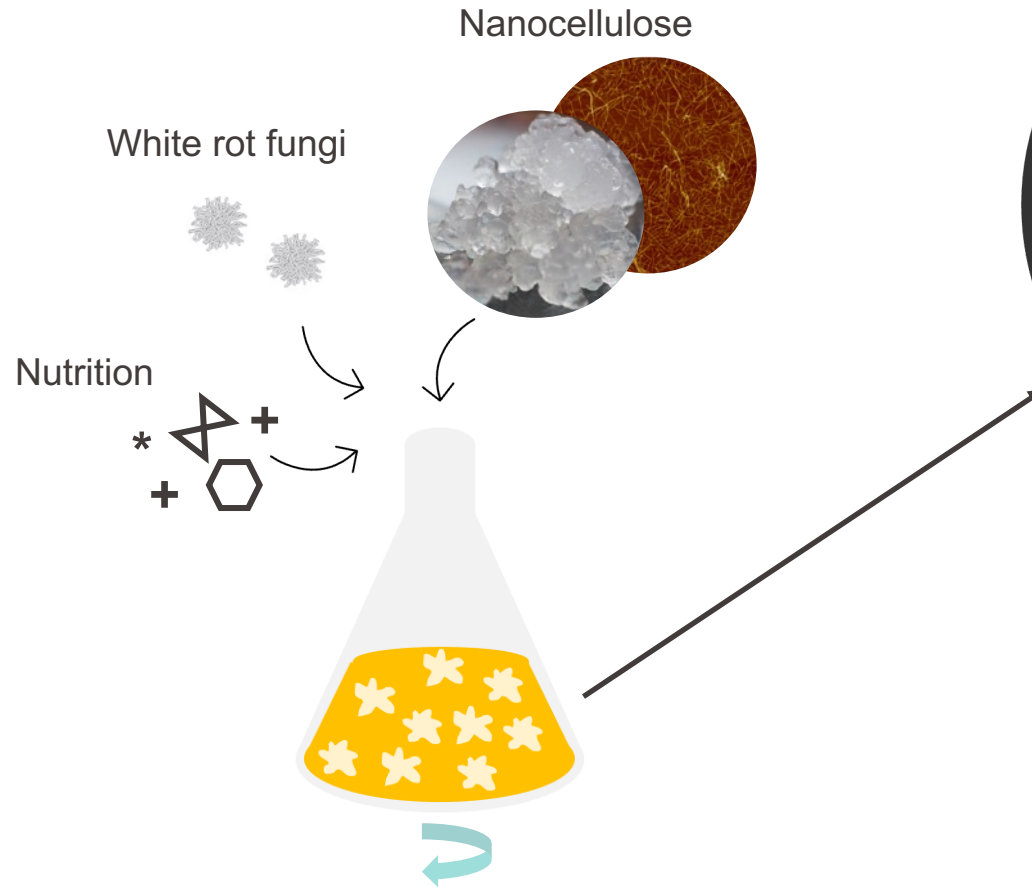


- Mycelium pellets
- Media that is depleted in nutrition
- Media that is enriched in exopolysaccharides (EPS)

Dinius, et al., Physical Sciences Reviews **9** (2023).

Nanocellulose as an additive, not a nutrient

Submerged fermentation

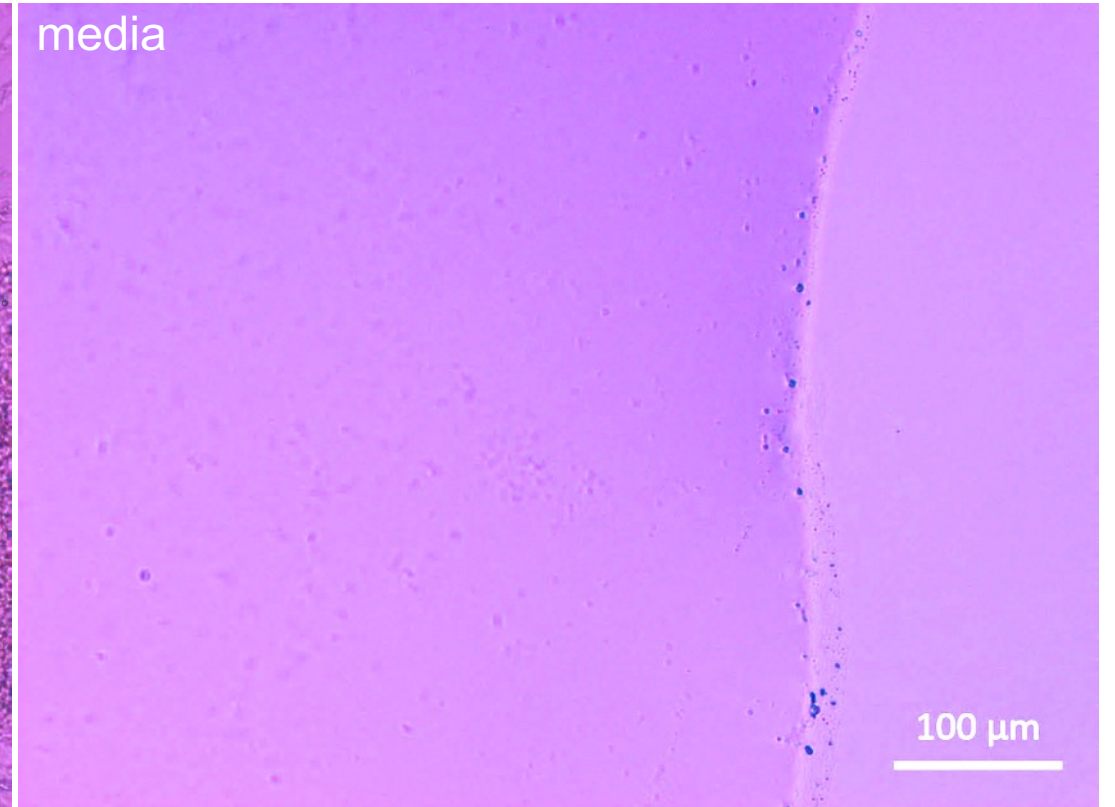
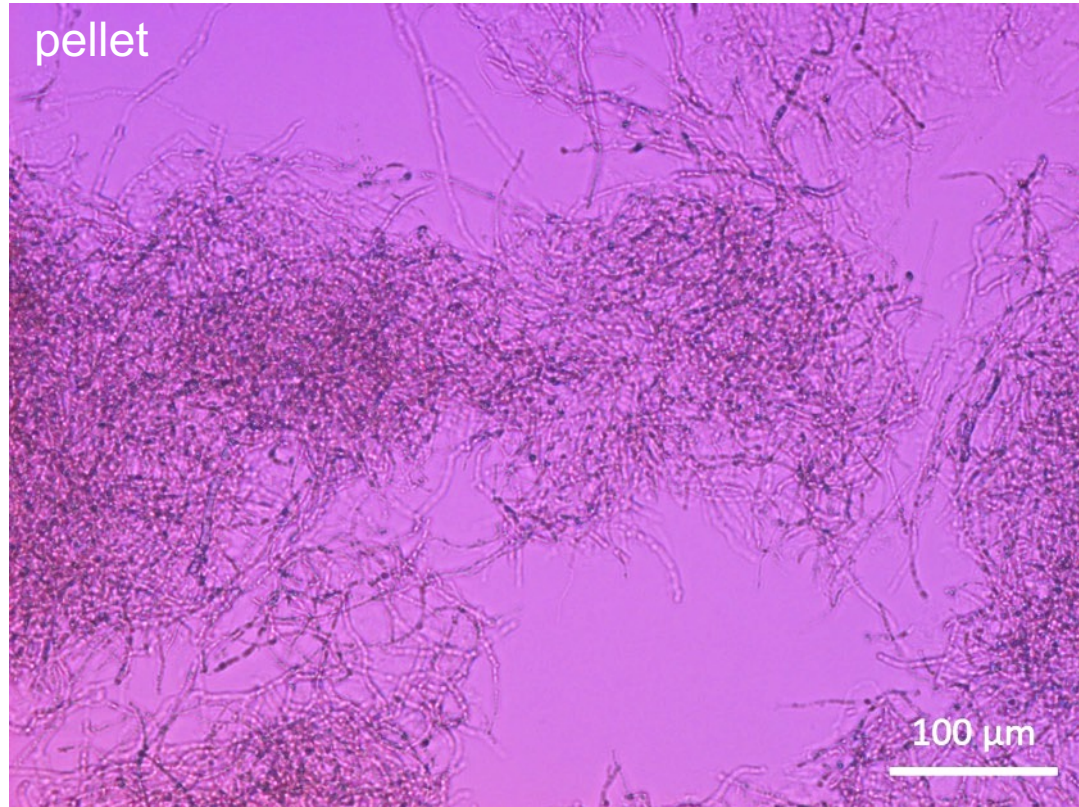


- ✓ Species – *T. ochracea*
- ✓ Humidity – 100%
- ✓ Temperature – 25 °C
- ✓ Time – 14 days
- ✓ Nutrition – protein and sugar-rich media
- ✓ Additive – nanocellulose

Mycelium growth without added nanocellulose



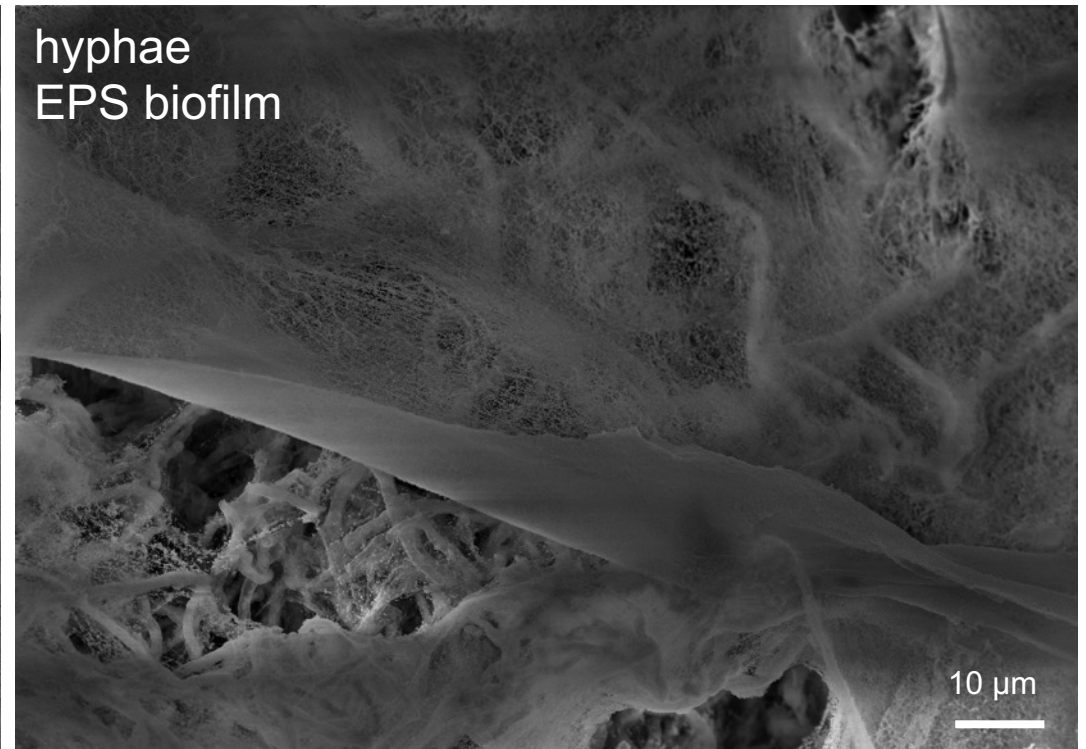
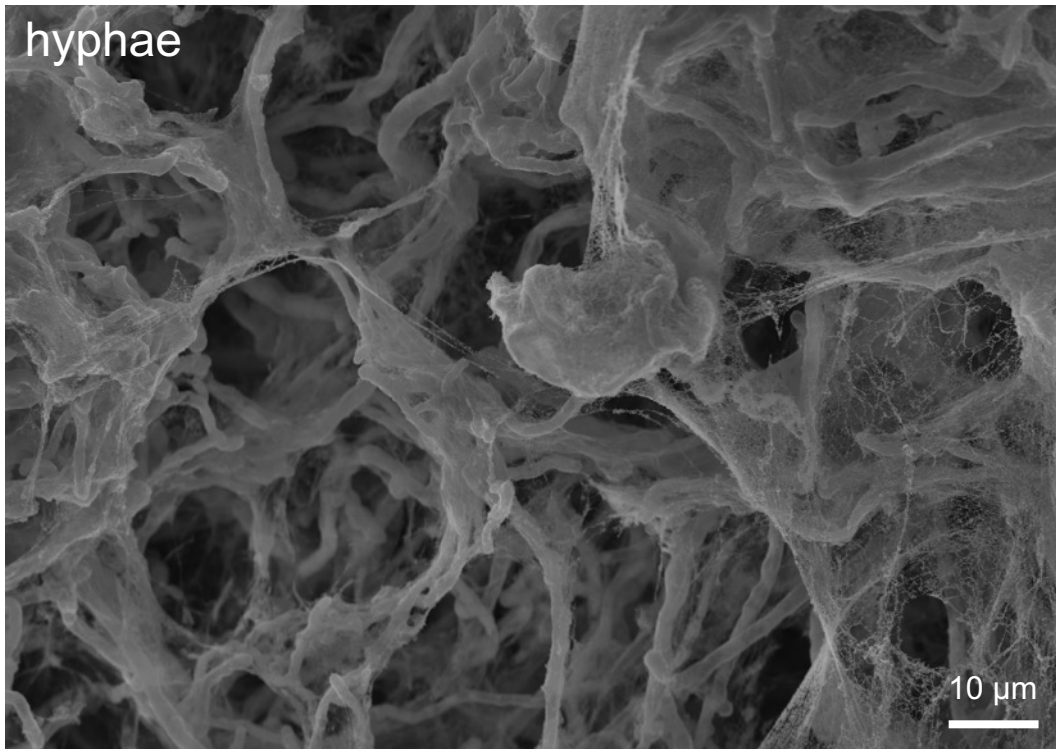
- Deactivate
- Dialyze (12-14 kDa)
- Solid part (mycelium) and liquid part (EPS)



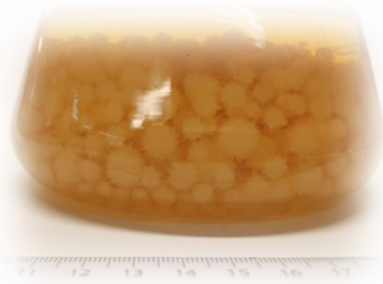
Mycelium growth without added nanocellulose



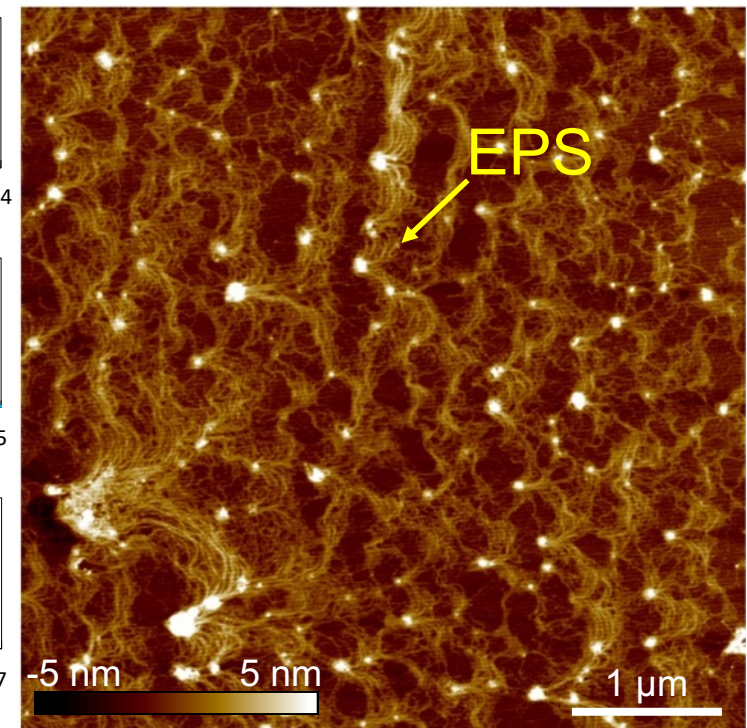
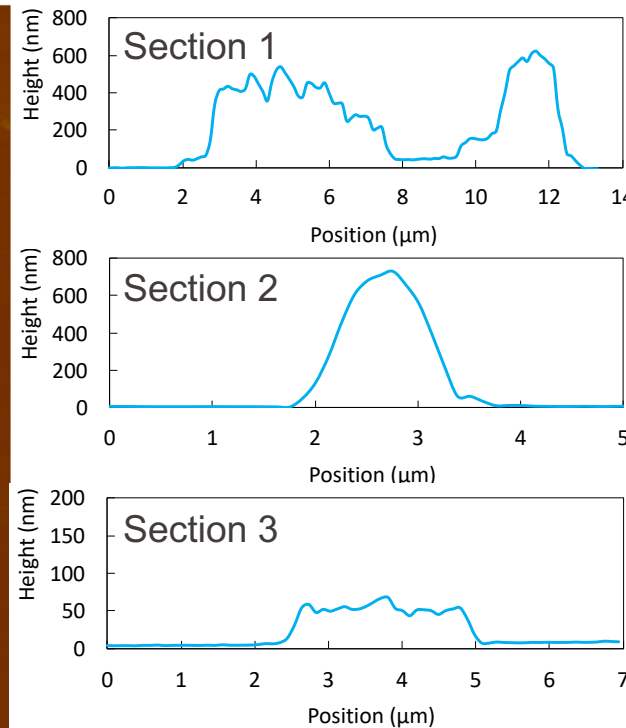
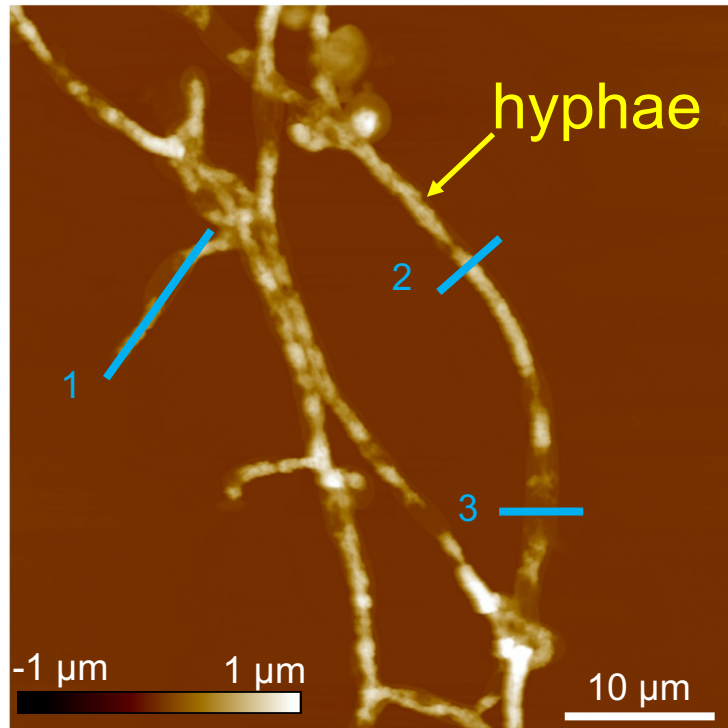
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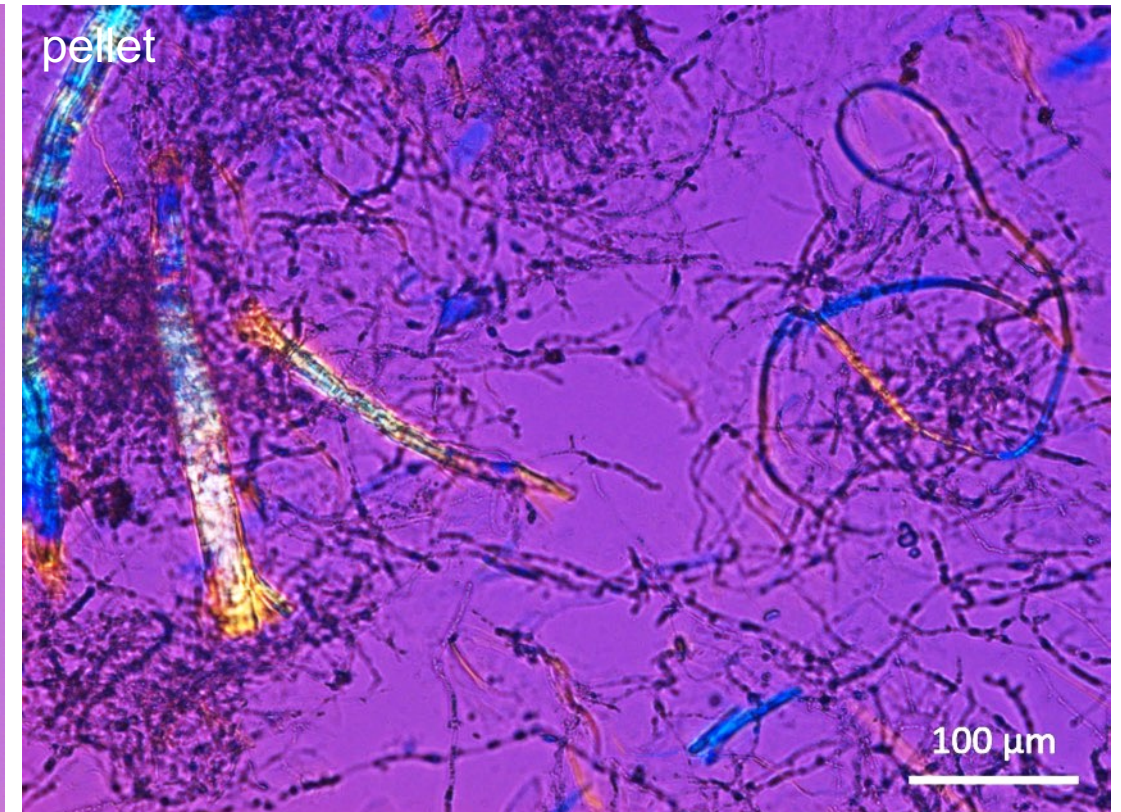
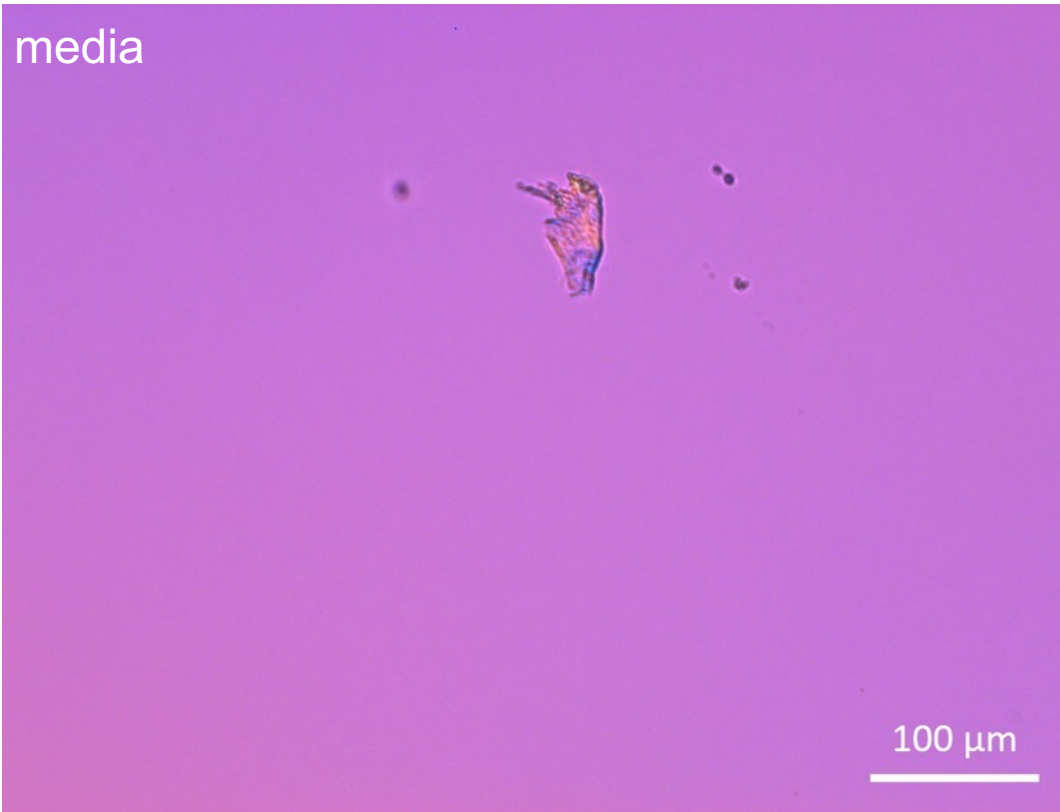
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Mycelium growth with added nanocellulose



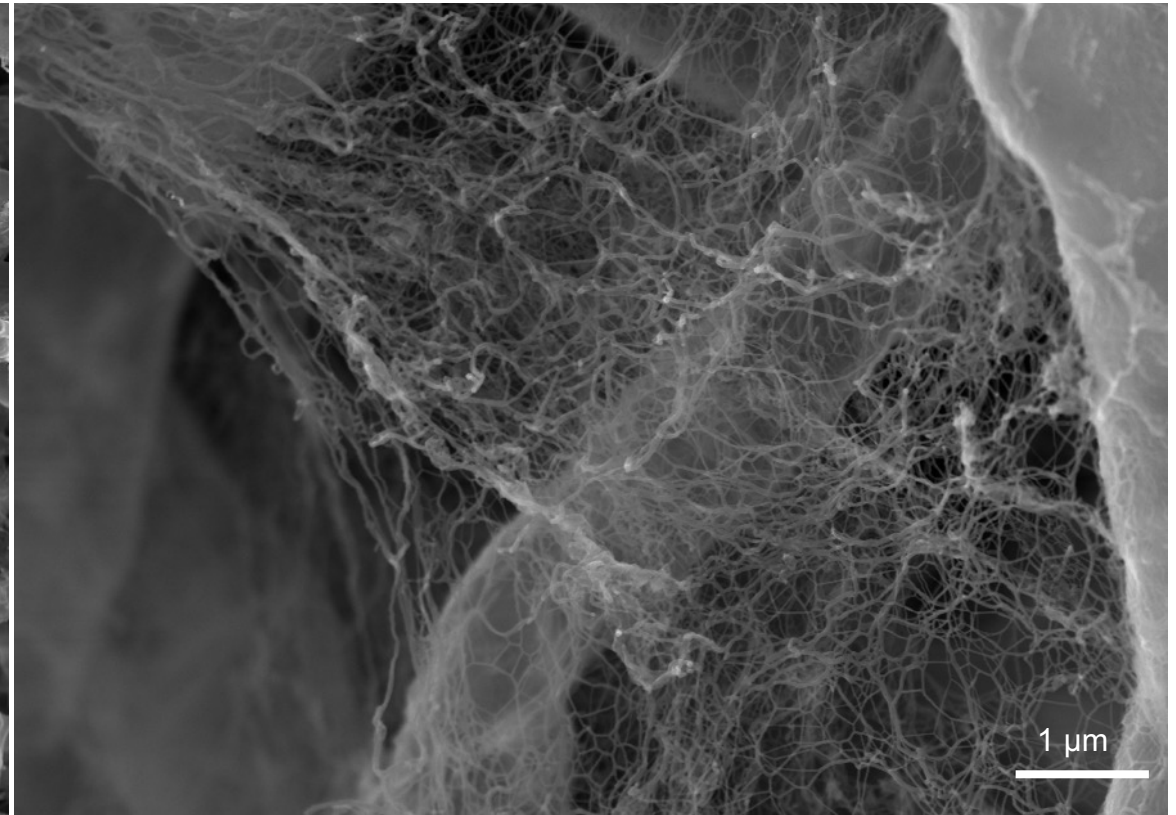
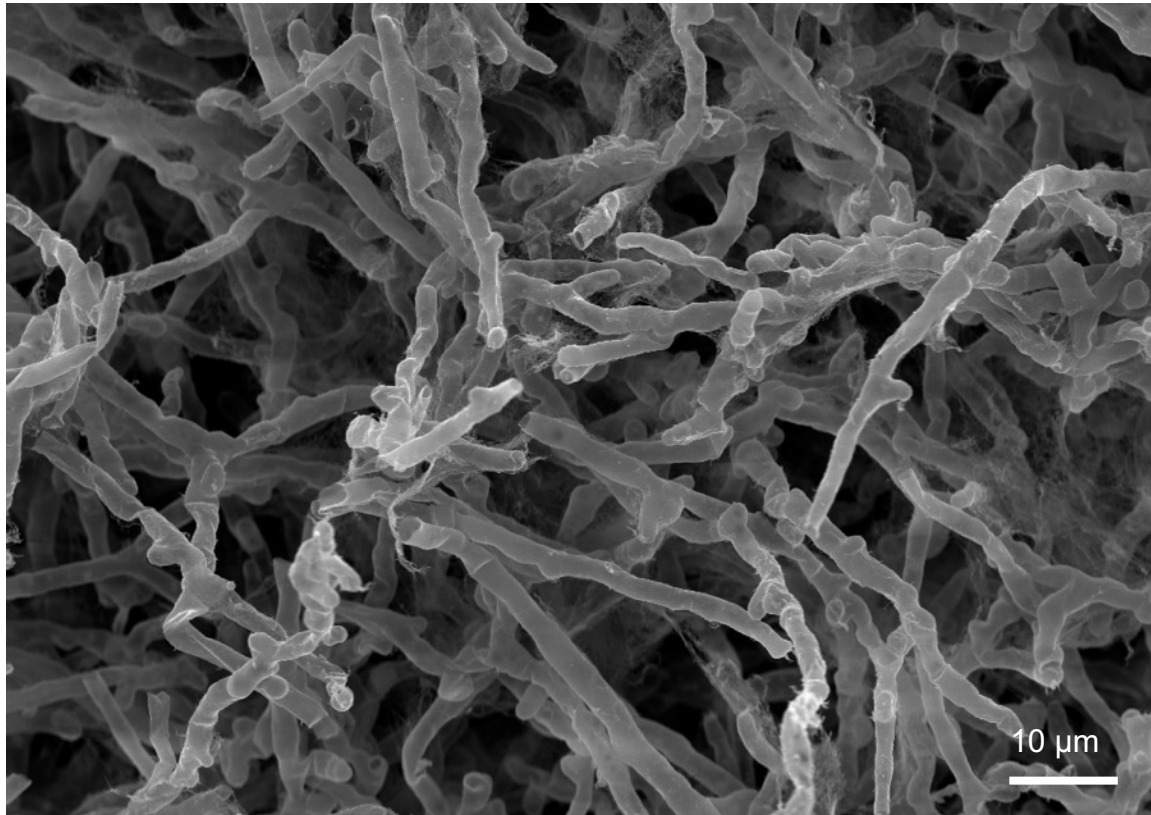
- Deactivate
- Dialyze (12-14 kDa)
- Solid part (mycelium) and liquid part (media)
- Where's the nanocellulose?



Mycelium growth with added nanocellulose



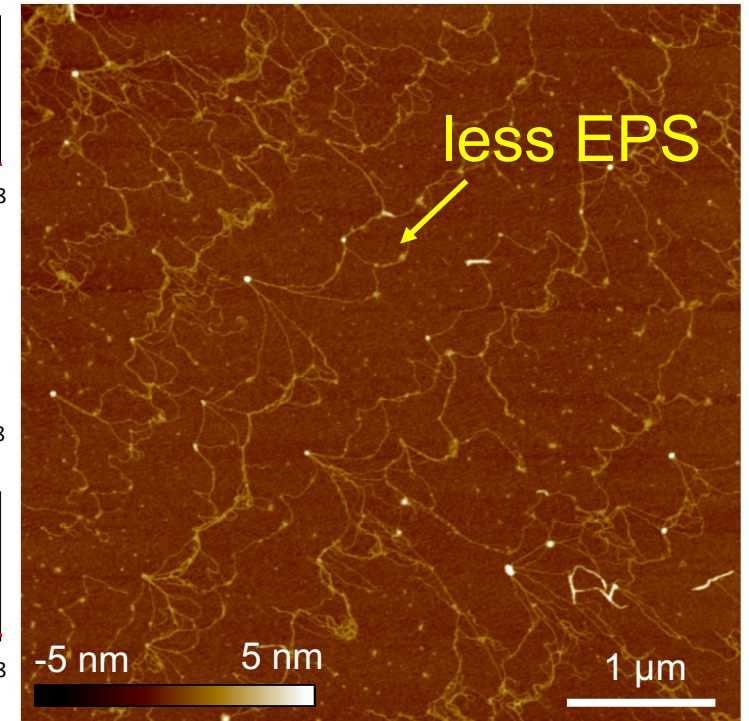
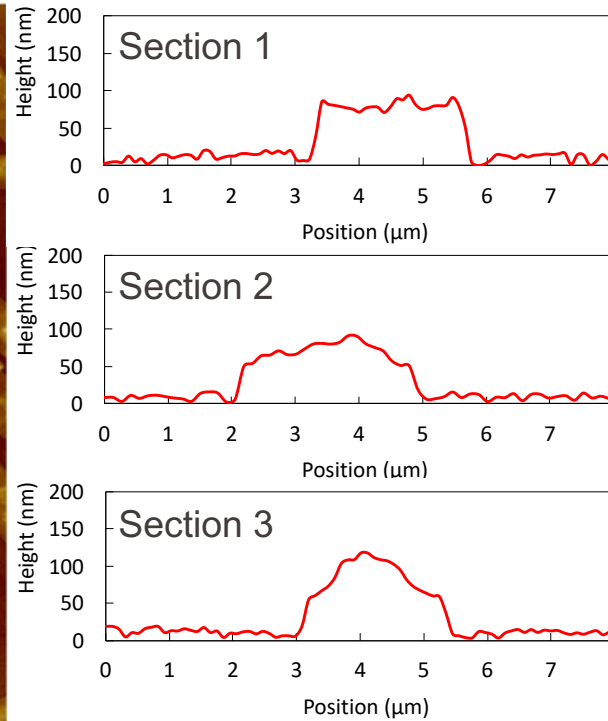
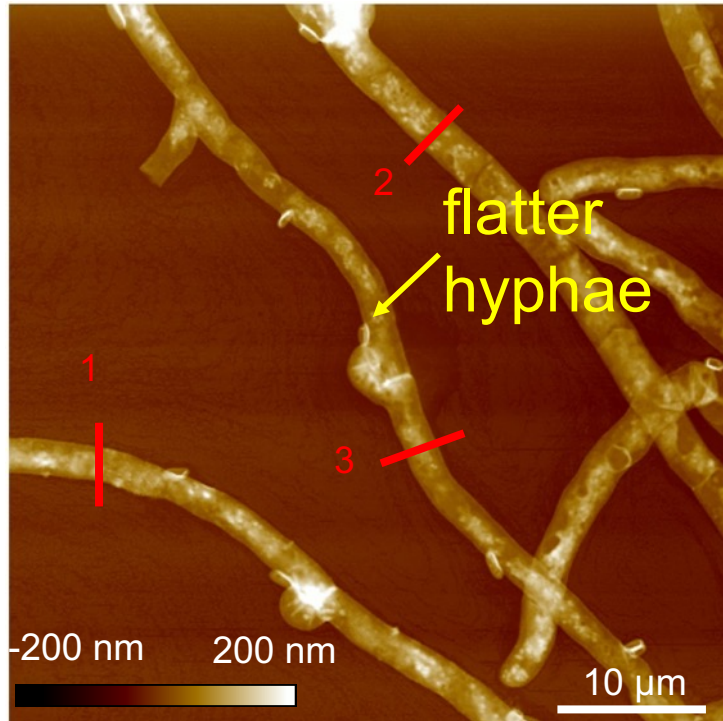
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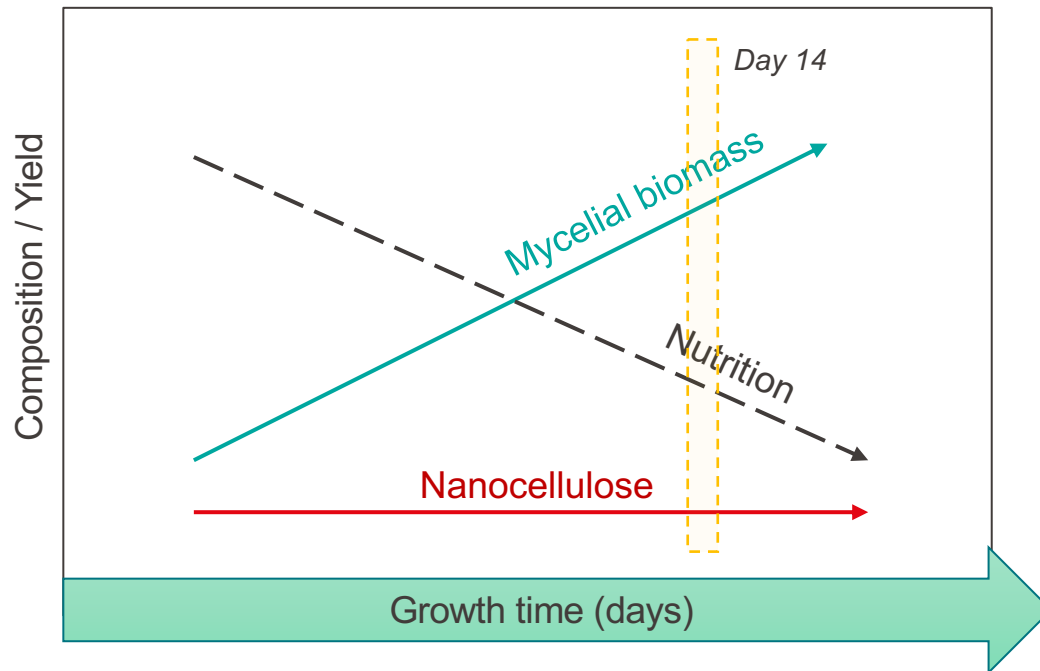
Mycelium growth with added nanocellulose



- Deactivate
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- Where's the nanocellulose?



Growth time and additive to modify composition and properties



- Biomass composition depends on when growth is stopped
- Under conditions of ample nutrition, nanocellulose content is fixed
- Whether nanocellulose is located in the pellets or in the surrounding medium depends on growth time
- After 14 days, all nanocellulose is in the mycelium pellets

Take aways

- Growth environment is a powerful lever in remodeling the cell wall of fungi and its extracellular outputs
- The ability of fungi to bind diverse materials can be harnessed to create functional (bio)nanocomposites through growth (this is what we study!)
- How can we tune composition and function via growth?

Thank you!

