Arbuscular Mycorrhizal Growth Modelling

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Biological Question

During Fungal development how does fungal hyphae grow ?

Is there any pattern to the branching of Arbuscular Mycorrhiza Network (AMN) ?

How is fungal growth abundance affected by presence of nearby bacterial species?

Model Organism - Arbuscular Mycorrhizal Fungi

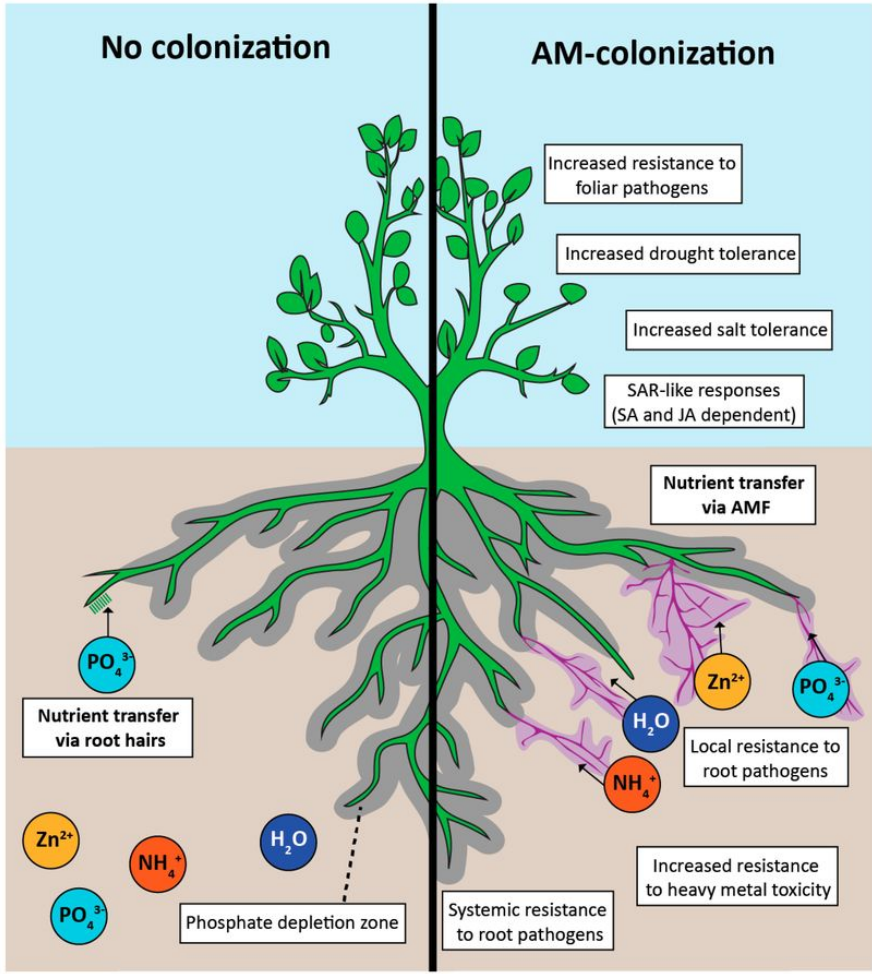
Arbuscular Mycorrhiza (AM)

AM are soil-borne fungi that can significantly improve plant nutrient uptake and resistance to several abiotic stress factors

Symbiosis between plants and members of the fungi phylum *Glomeromycota*

10-30% of plant-fixed carbon is transferred to the fungus

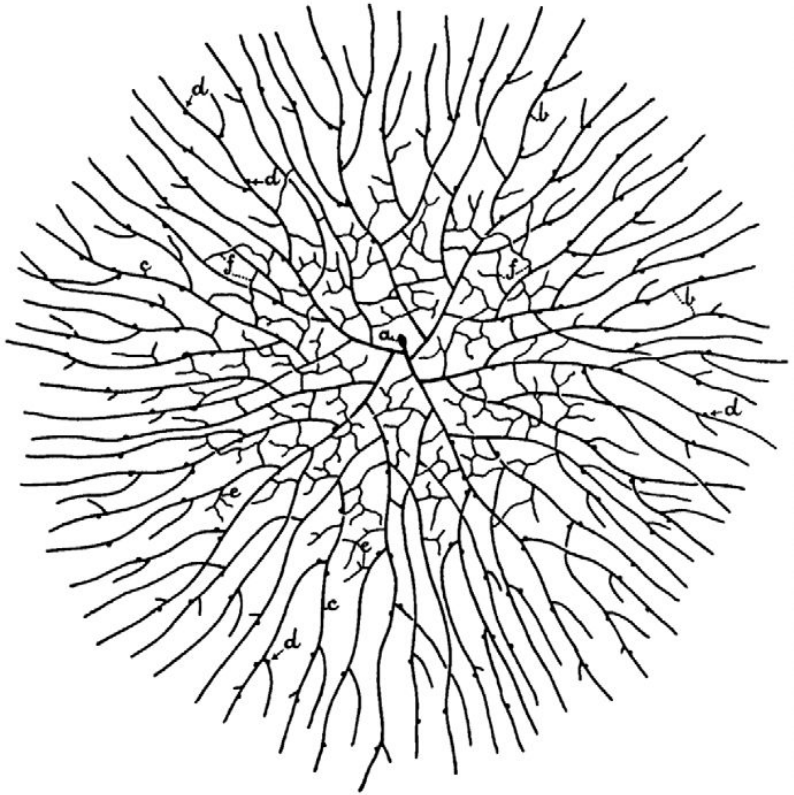
Nutrient transport occurs through symbiotic structures inside plant root cells known as arbuscules



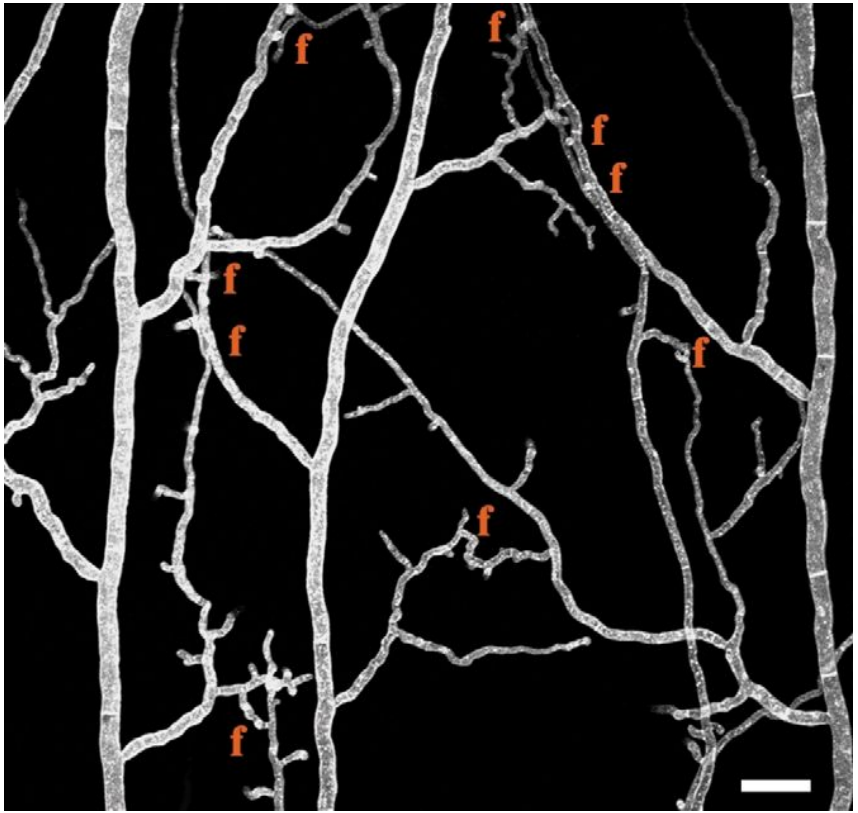
Parniske, Nature Reviews Microbiology (2008)
Sun et al., 2018

Wikipedia

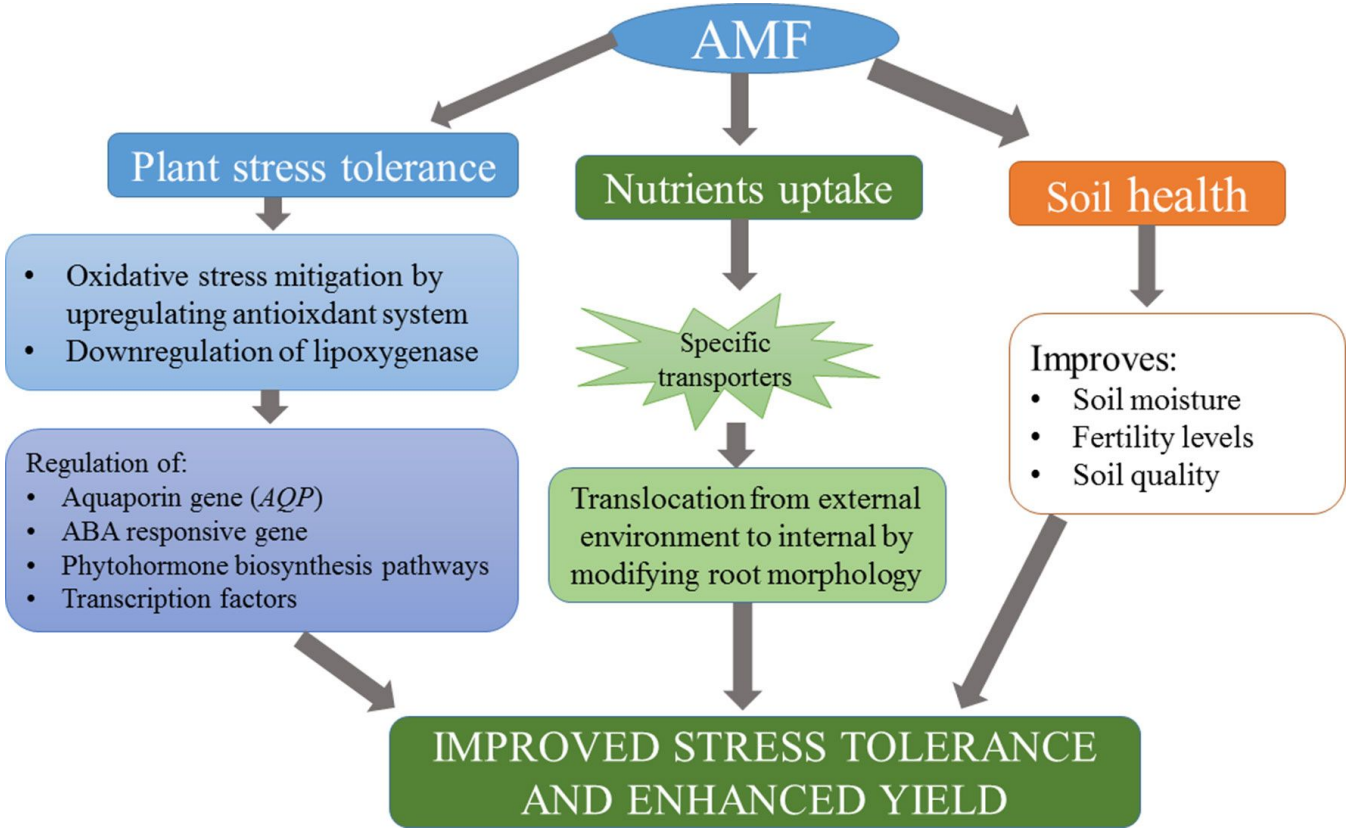
An interconnected fungal colony from a single spore



Projection of confocal images of the interconnected colony interior of Neurospora crassa showing hyphal fusions (f). Scale bar represents 50 mm

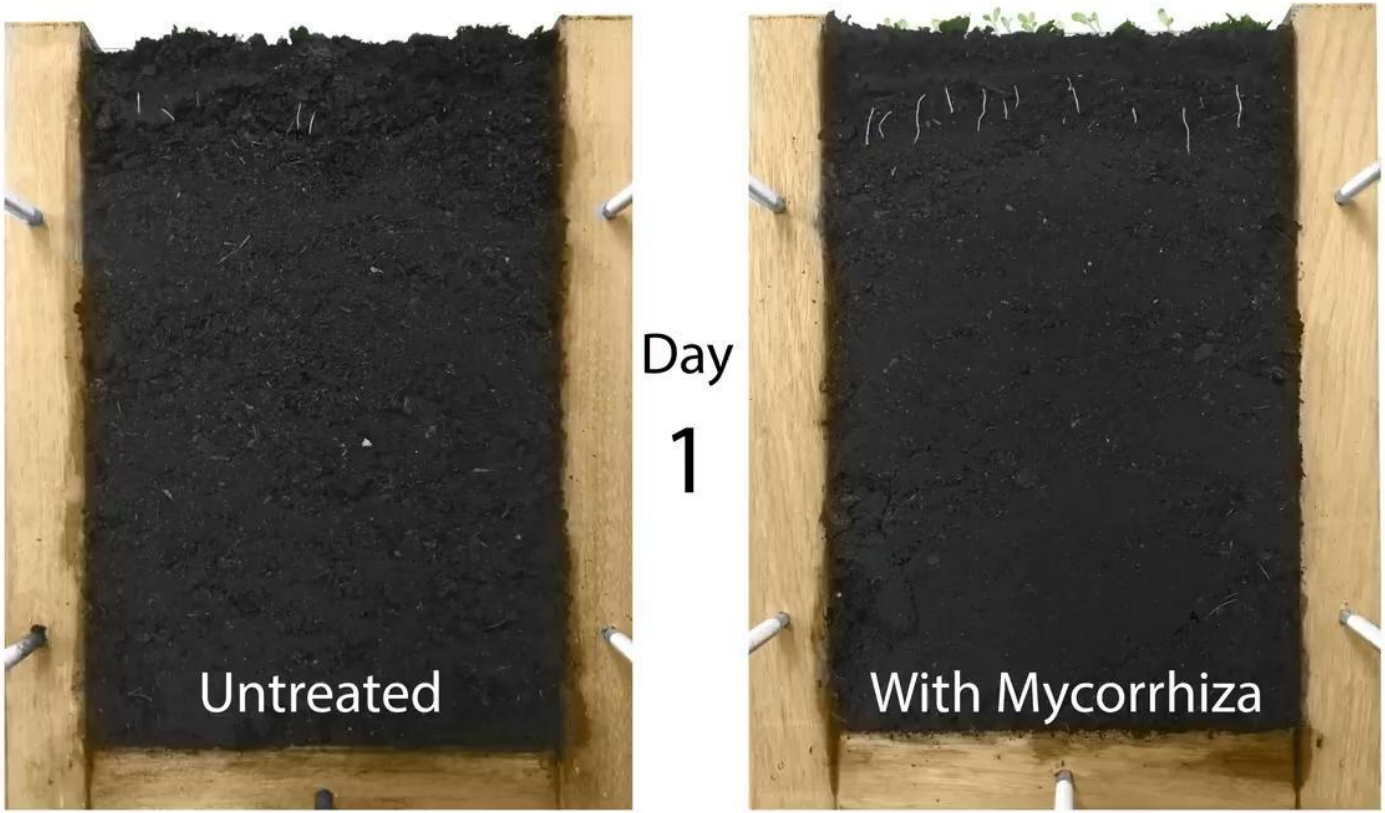


Regulatory Functions of AMN in the ecosystem



Begum et.al, Front. Plant Sci.,2019

Effect of Mycorrhiza on Plant root growth



Growth and branching as seen on a petri plate

Factors that affect AM growth

- Soil **Fertility**: nutrients (primarily **phosphorus** and **nitrogen**)
- **Temperature**: ideal temperature ~ **20–30°C**, spore formation is strongest at 35°C
- **Light**: not just photosynthetic products, also radiation
- **Bacteria**: by and large, increase mycorrhizae
- Interspecies **competition**

and so on…

Alkobaisy, 2022
Nagahashi, Douds, Mycologia 2004

Our Model

- **Nutrient gradient** and **space** are the fundamental driving forces

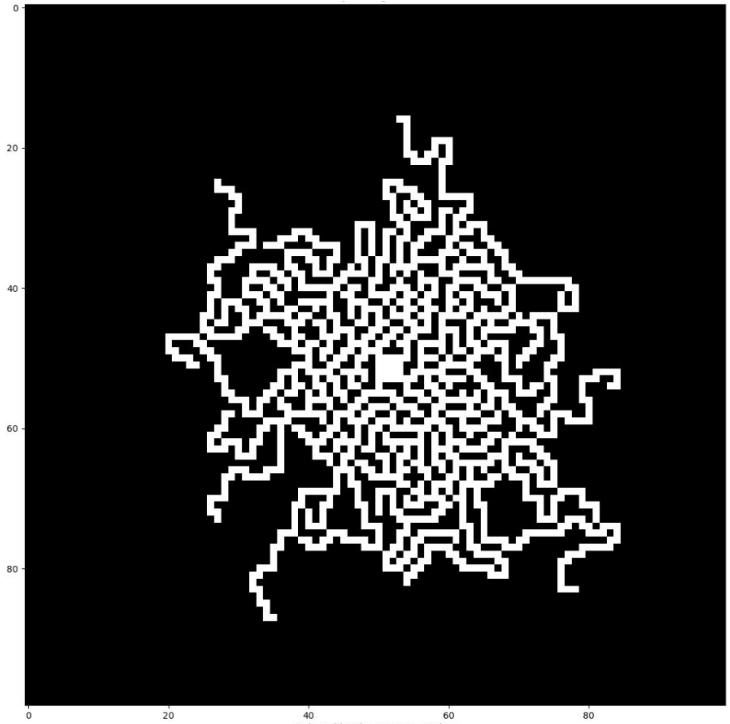
  Nutrient concentration (NC) - dependant on number of fungal cells in the immediate neighbourhood

- Greater the **degree of the node**, lesser the probability of branching

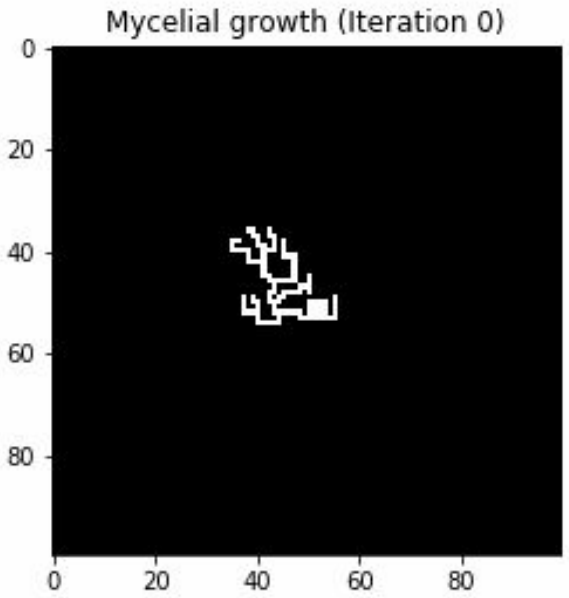
- Probability of growth at a point (P)- nutrient concentration at the point and nodal degree

- Stochastic element for uniform distribution - growth happens iff P> random number(n) st n $\in$[0,1]

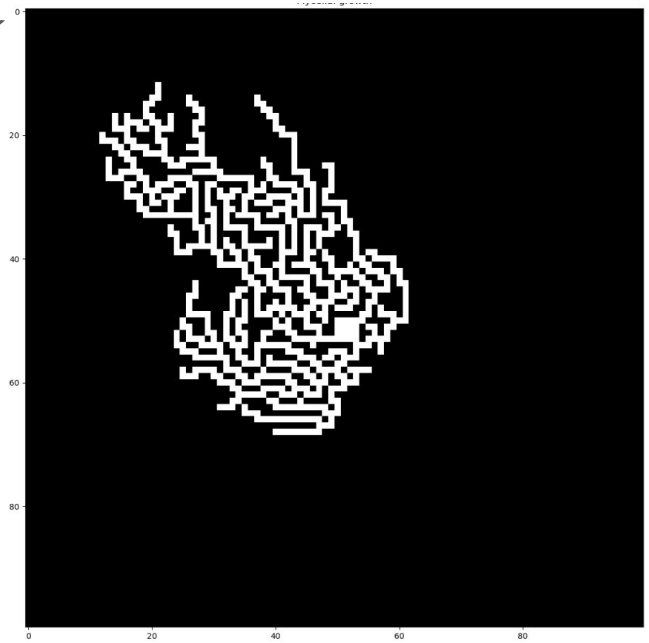
UNREGULATED GROWTH

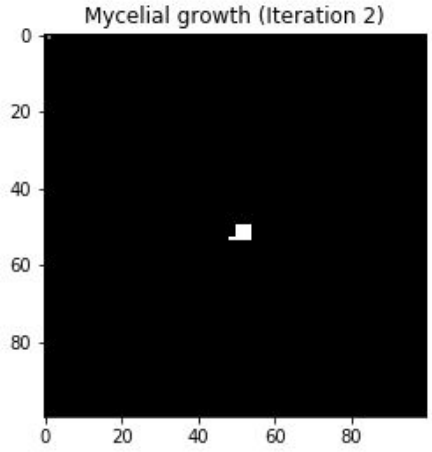


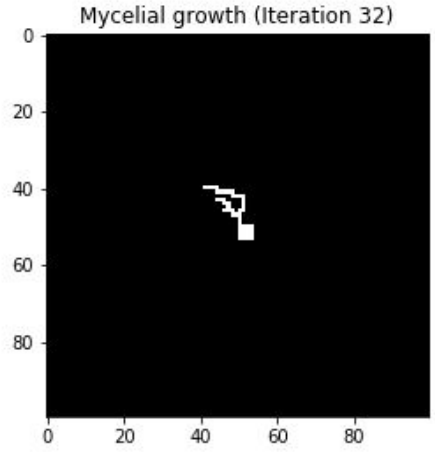
FUNGAL GROWTH

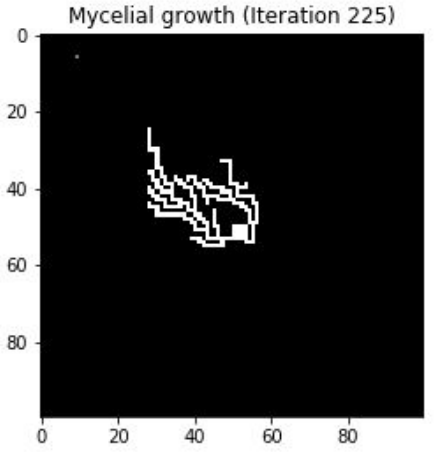


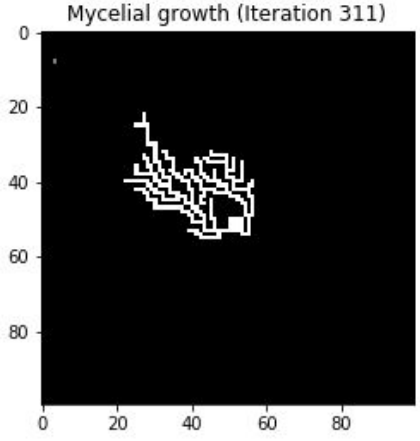
Fixed Source of Nutrition

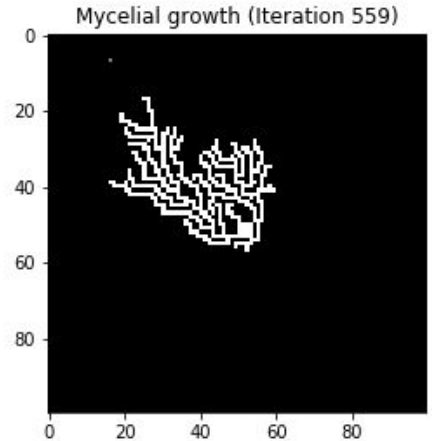


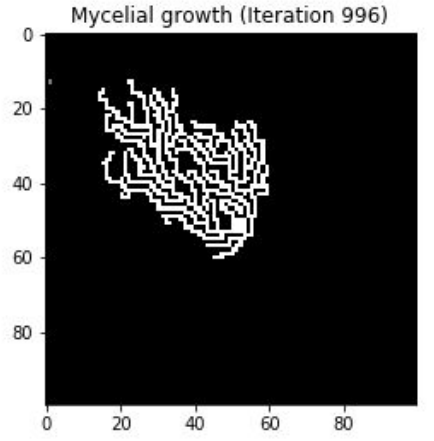

Mycelial growth (Iteration 2)
0
20
40
60
80
0
20
40
60
80


Mycelial growth (Iteration 32)
0
20
40
60
80
0
20
40
60
80


Mycelial growth (Iteration 225)
0
20
40
60
80
0
20
40
60
80


Mycelial growth (Iteration 311)
0
20
40
60
80
0
20
40
60
80


Mycelial growth (Iteration 559)
0
20
40
60
80
0
20
40
60
80


Mycelial growth (Iteration 996)
0
20
40
60
80
0
20
40
60
80


THANK YOU