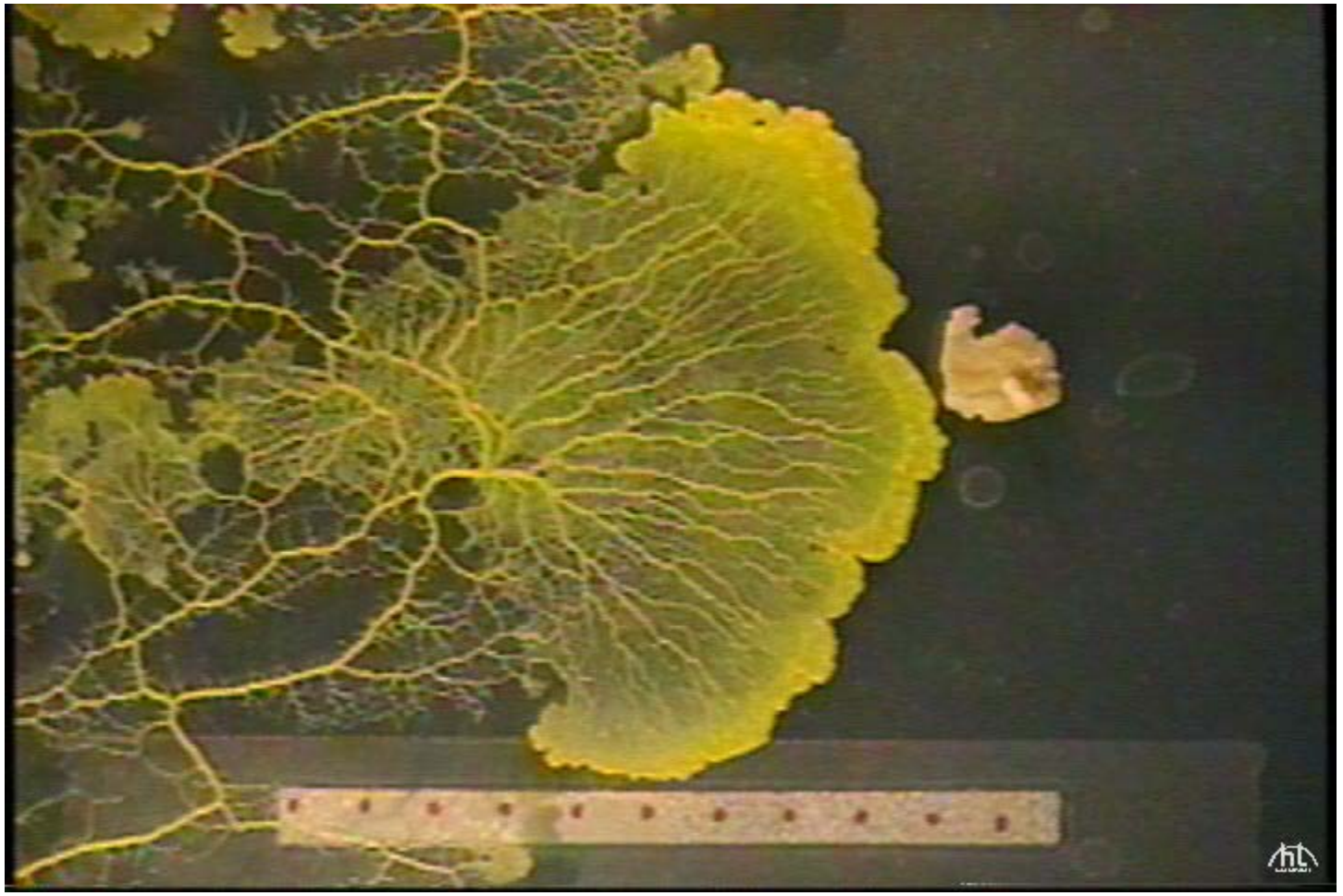
Algorithms in Nature

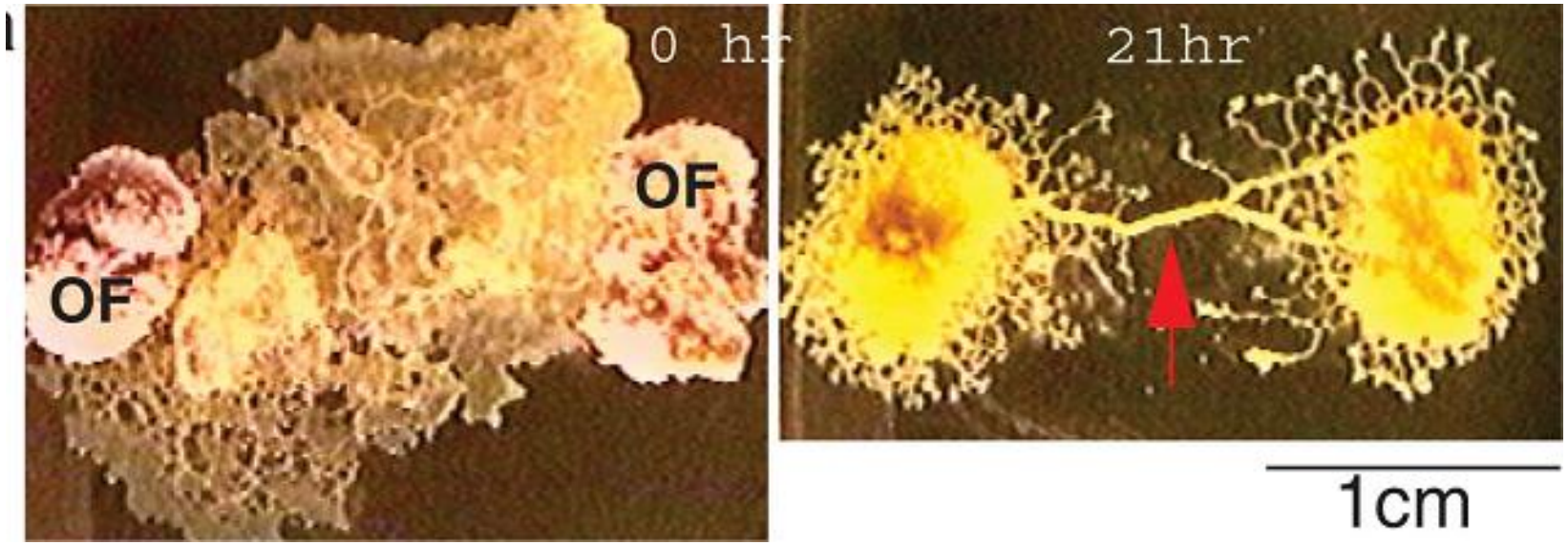
Slime mold network design

Physarum polycephalum

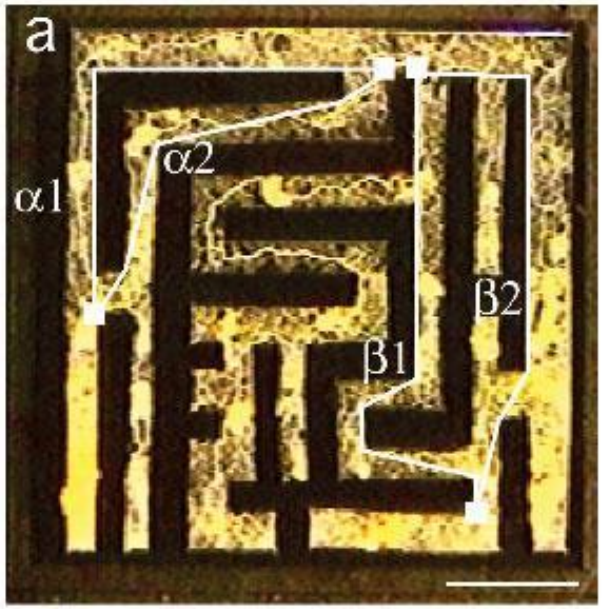


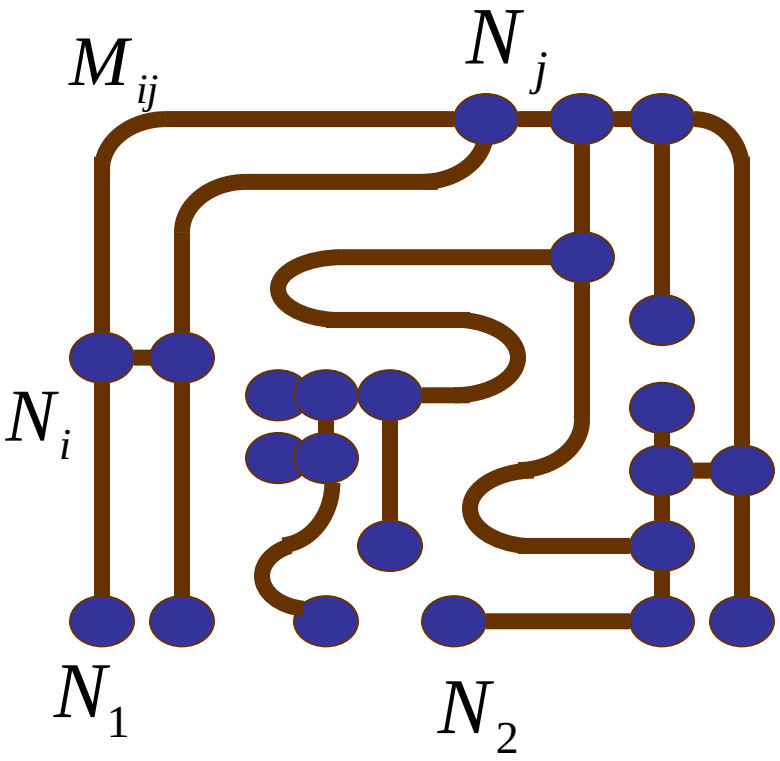
1cm

Physarum polycephalum



Discrete Form





N_i $p_i(t)$ Pressure

N_1 Start point

N_2 Goal

M_{ij} L_{ij} Length

$D_{ij}(t)$ Conductivity

$Q_{ij}(t)$ Flux

Modeling of the flux

N_i $p_i(t)$ Pressure

M_{ij} L_{ij} Length

$D_{ij}(t)$ Conductivity

$Q_{ij}(t)$ Flux

$p_i(t)$ Electric Pressure

$\frac{L_{ij}}{D_{ij}(t)}$ Electric Resistance

$Q_{ij}(t)$ Electric Current

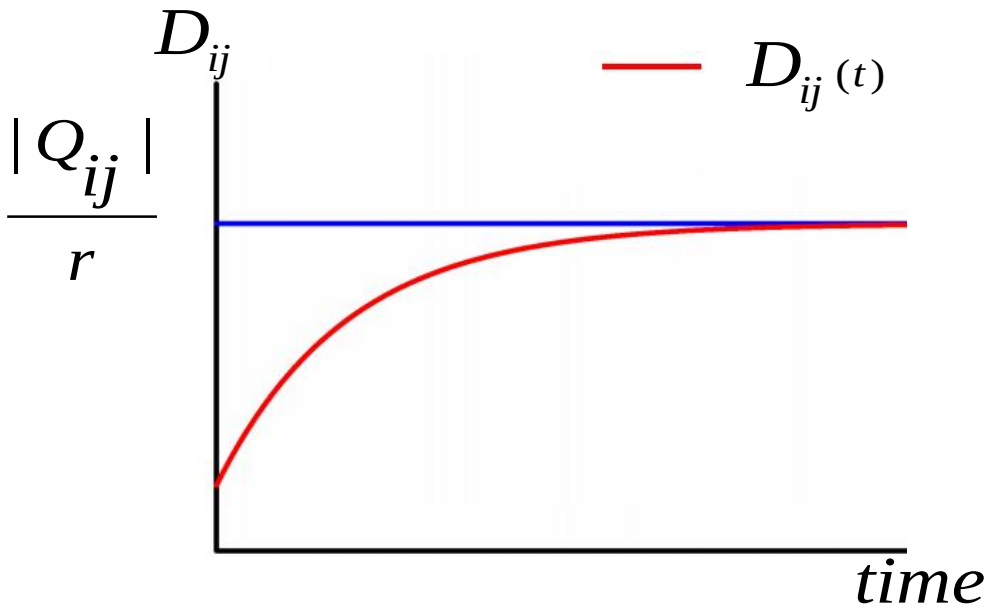
$$Q_{ij} = \frac{D_{ij}}{L_{ij}}(p_i - p_j)$$

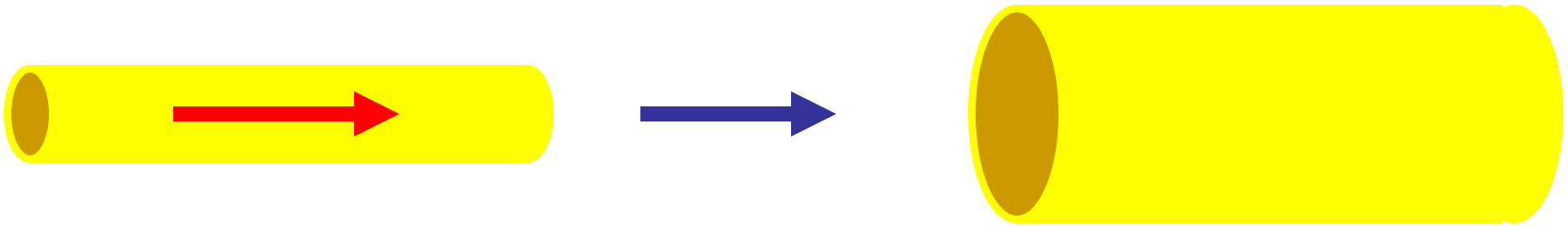
Modeling of the tube growth

$$\frac{d}{dt} D_{ij} = |Q_{ij}| - rD_{ij}$$

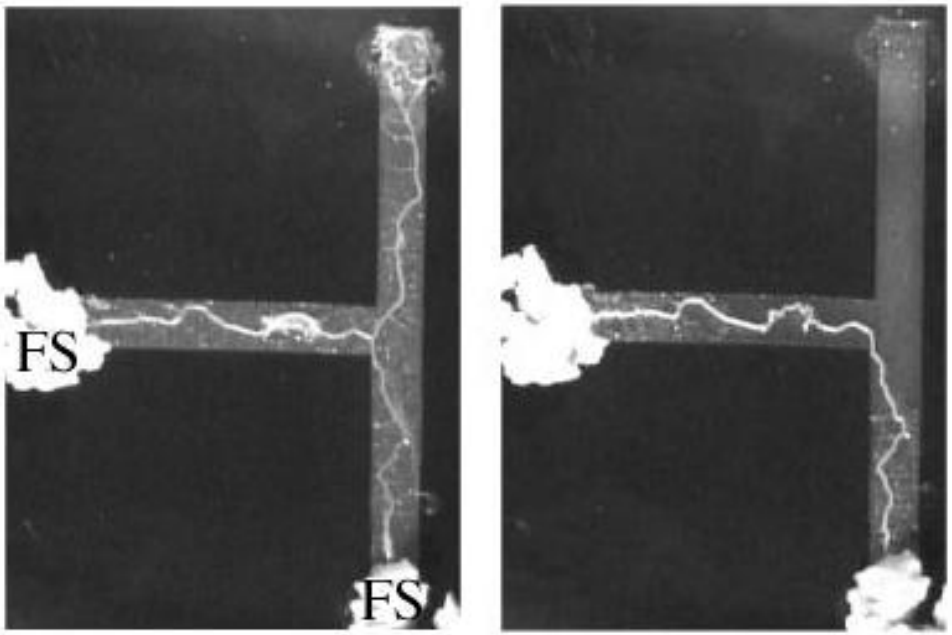
r :degenerate rate

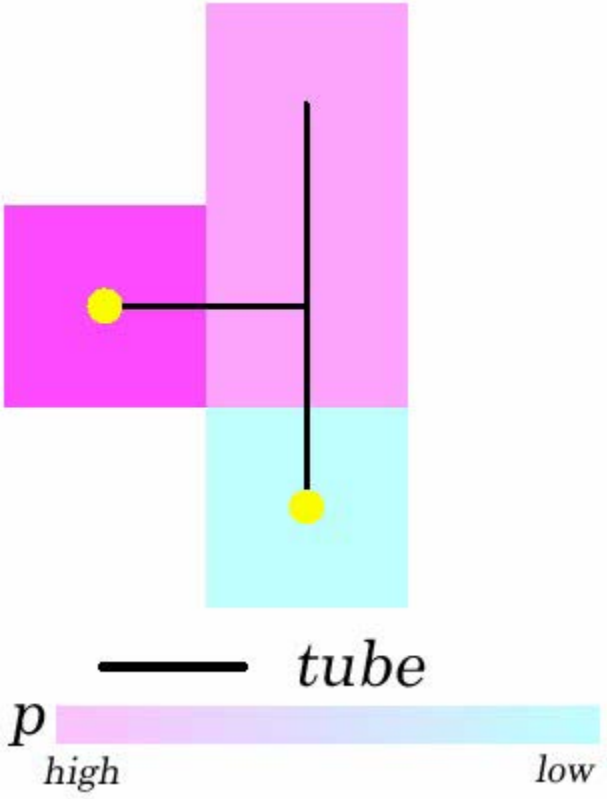
(constant)





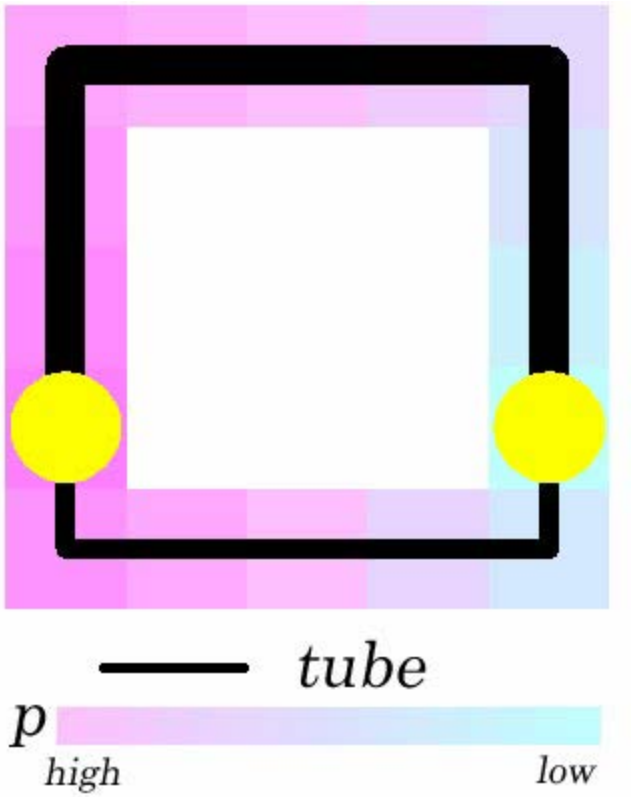
T shape vessel

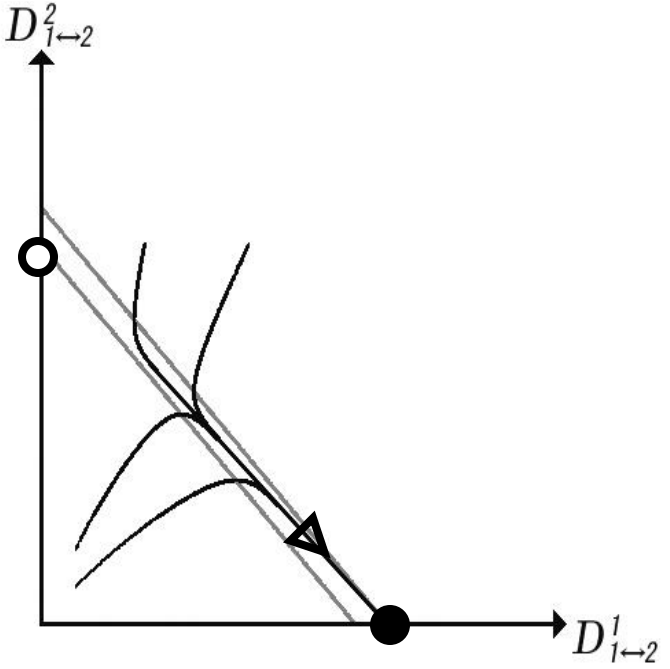




The tube at dead end disappears

Ring shape vessel $(L_{12}^1 \neq L_{12}^2)$



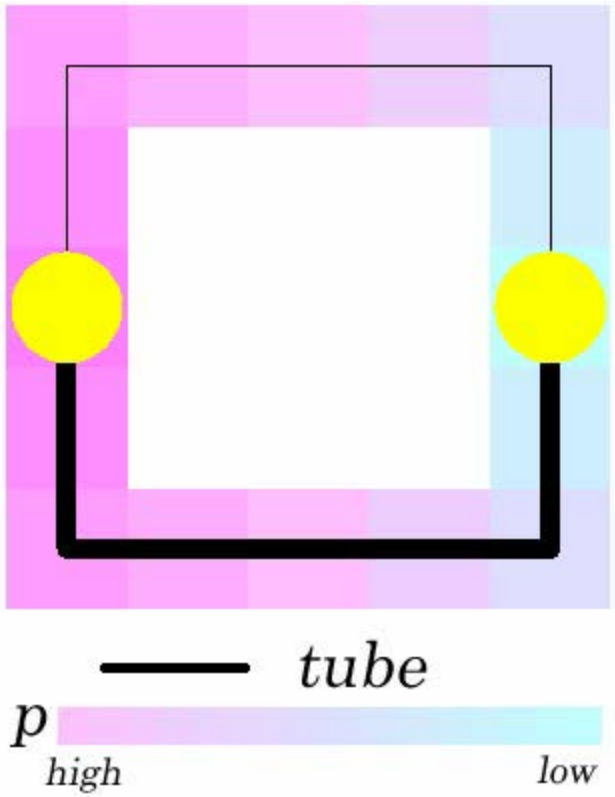


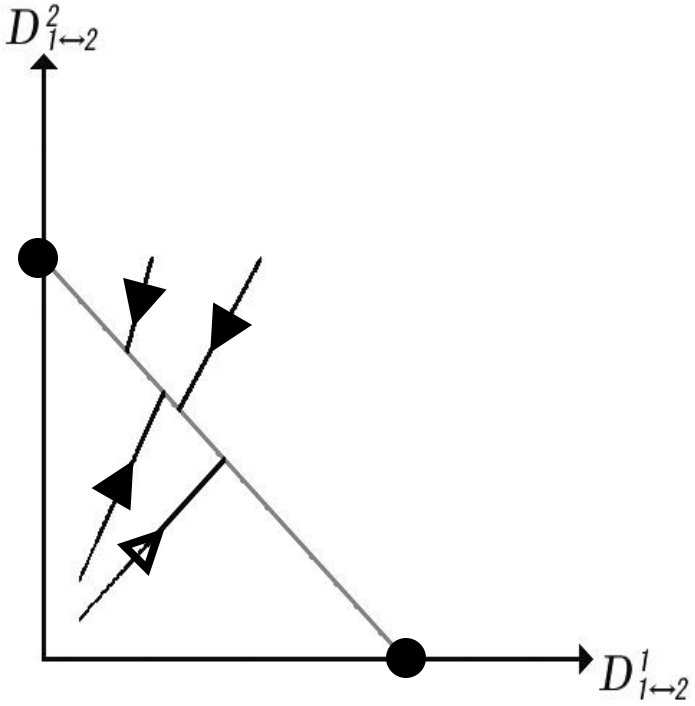
● Stable equilibrium point

○ Unstable equilibrium point

Only shortest tube remains

Ring shape vessel $(L_{12}^1 = L_{12}^2)$



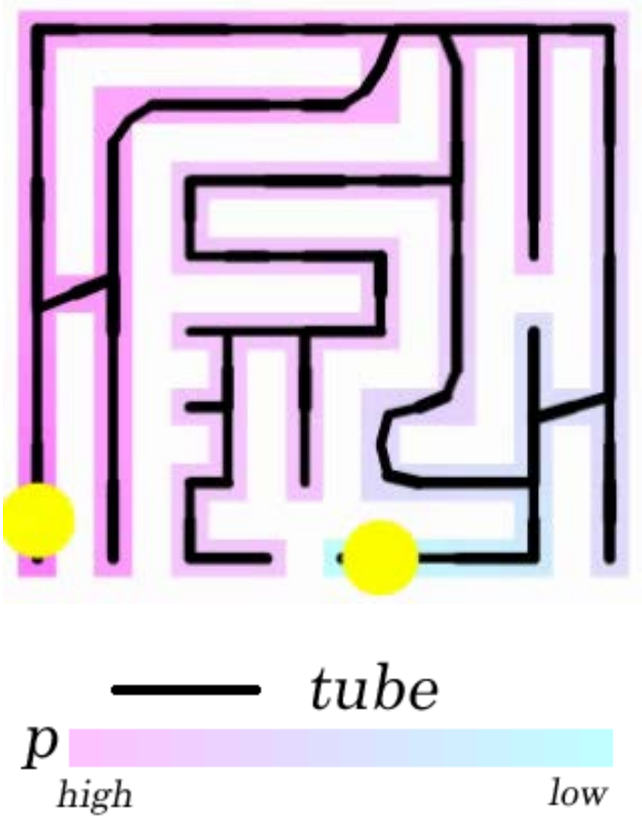


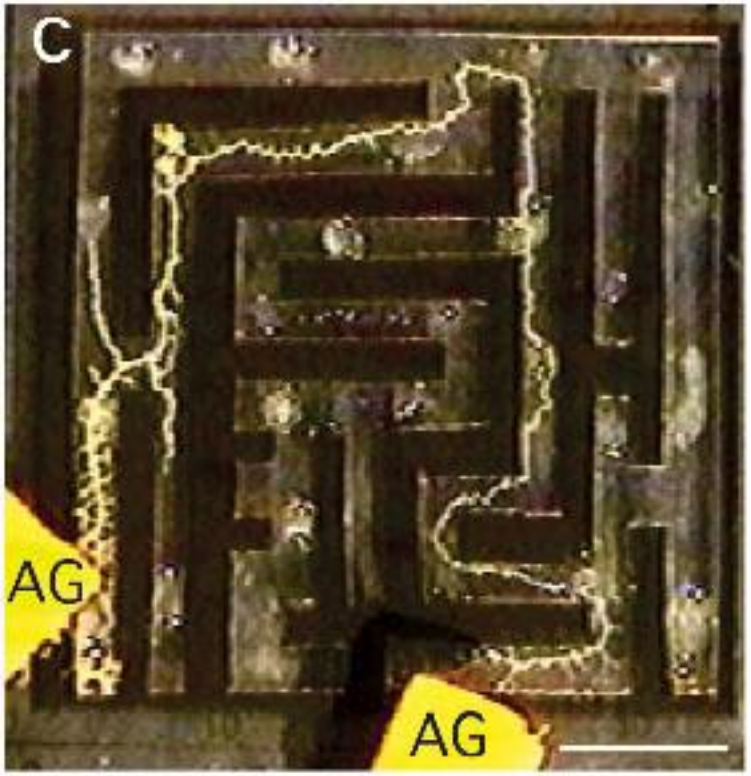
● Stable equilibrium point

○ Unstable equilibrium point

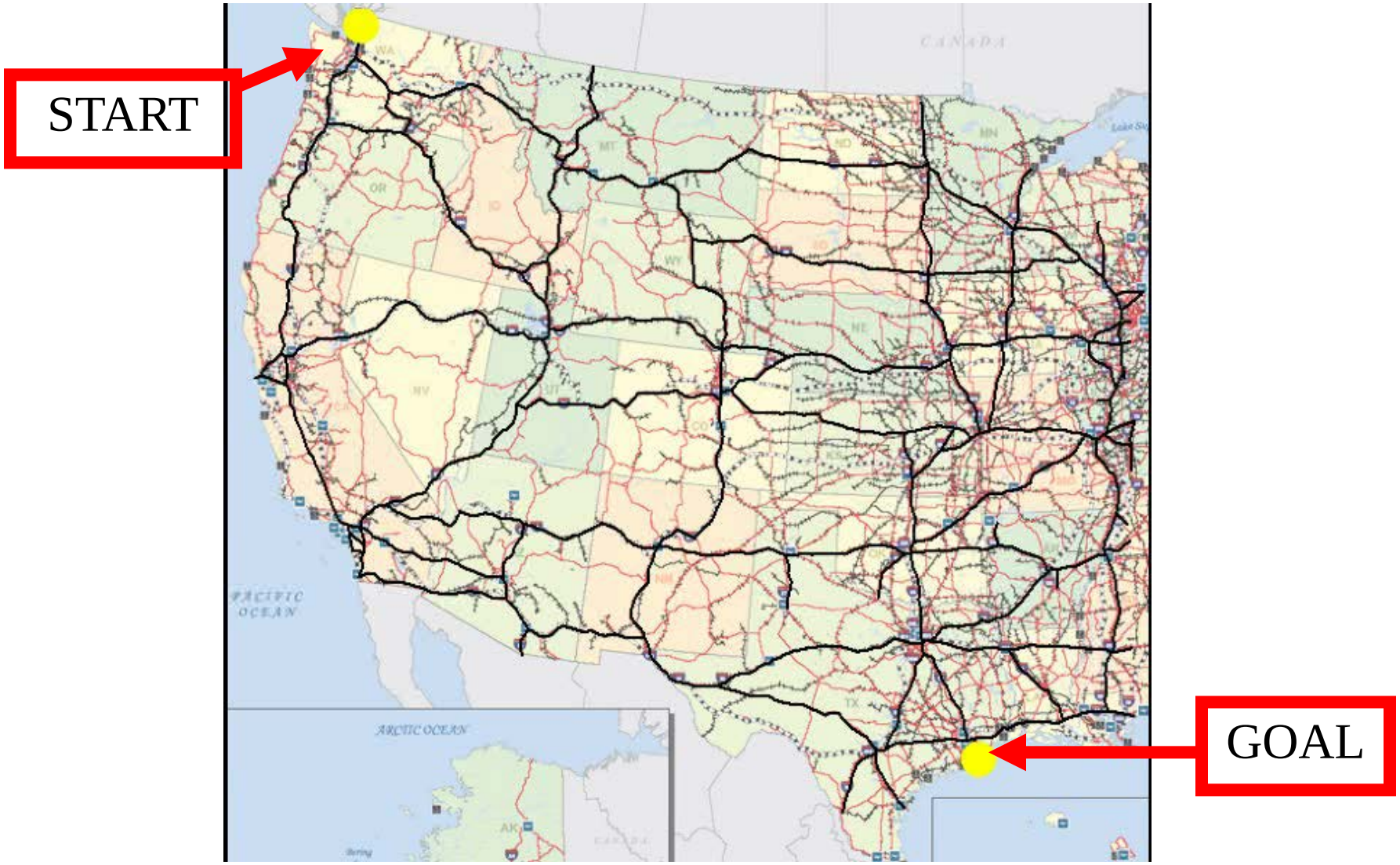
Both tubes remain

Solving Maze

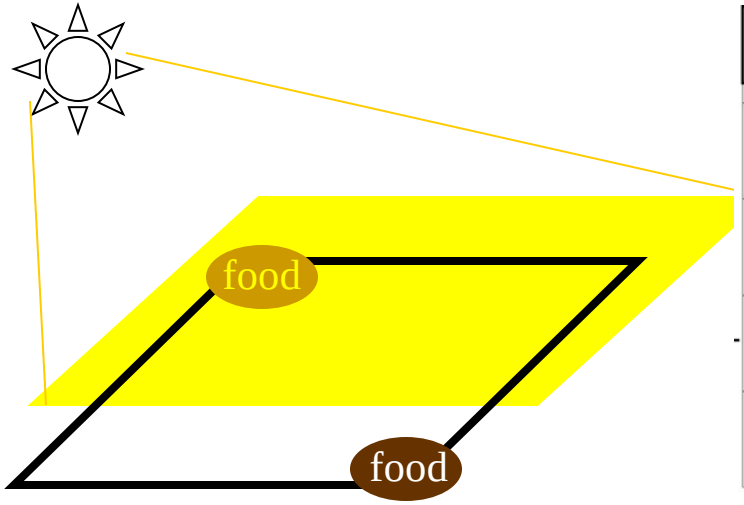


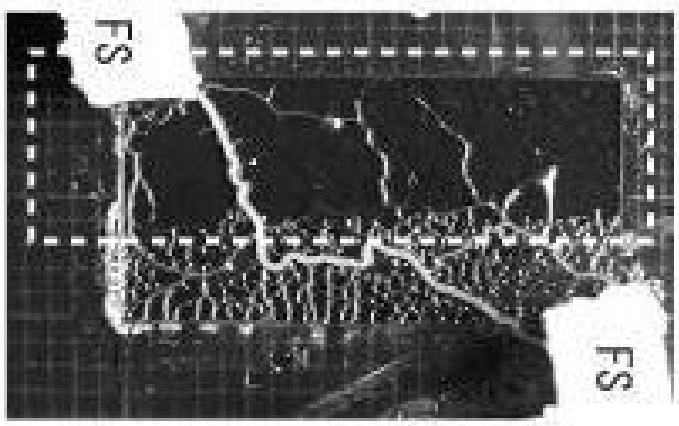


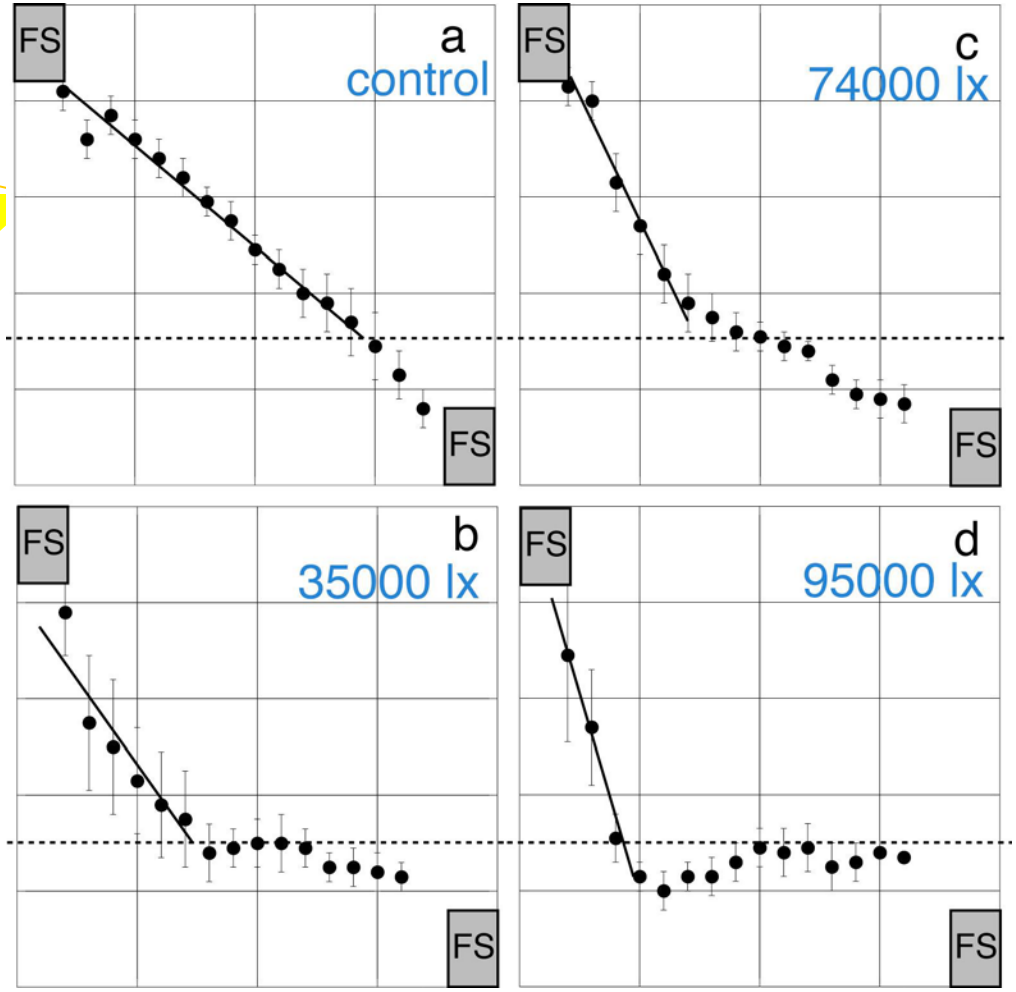
Apply for road navigation system



Using constraints for limiting search space



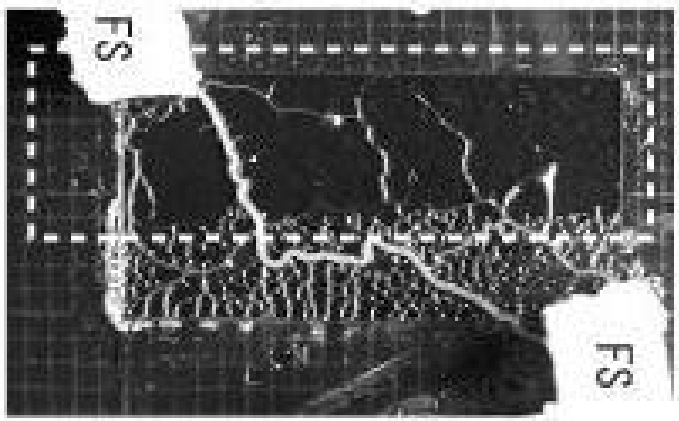


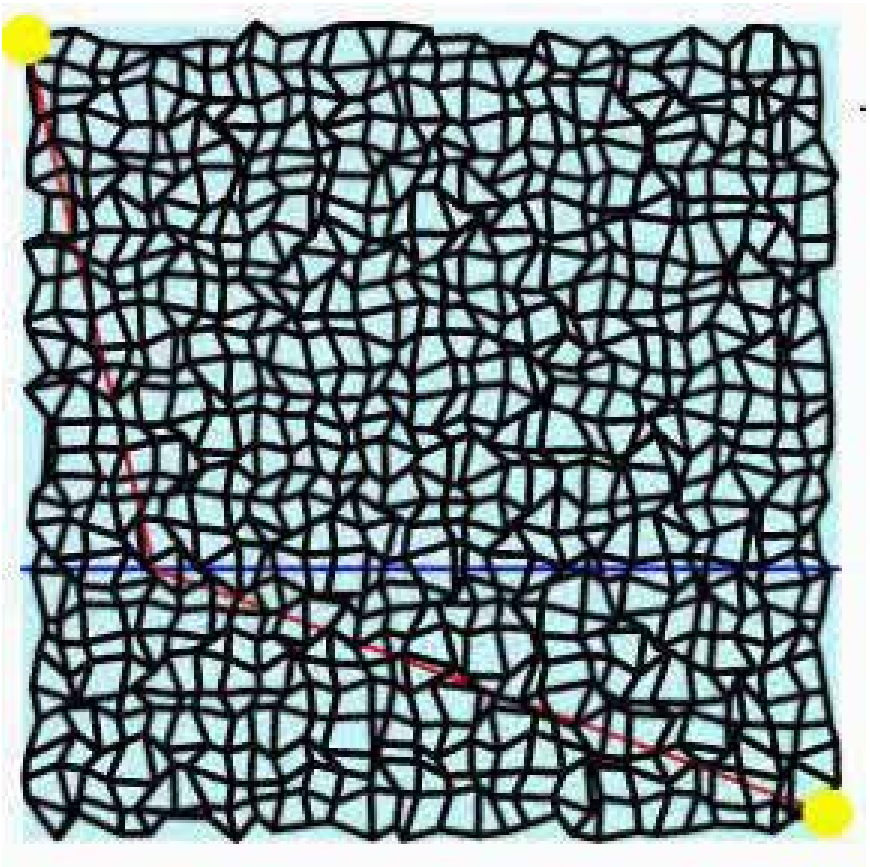


Ex 2. Shortest path on Weighted graph

$$\frac{d}{dt} D_{ij} = |Q_{ij}| - r_{(x)} D_{ij}$$

$$r_{(x)} = \begin{cases} 3 \\ 1 \end{cases}$$





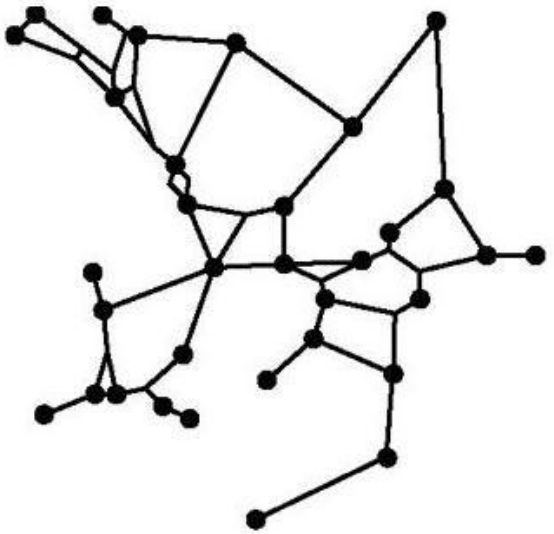
tube

p

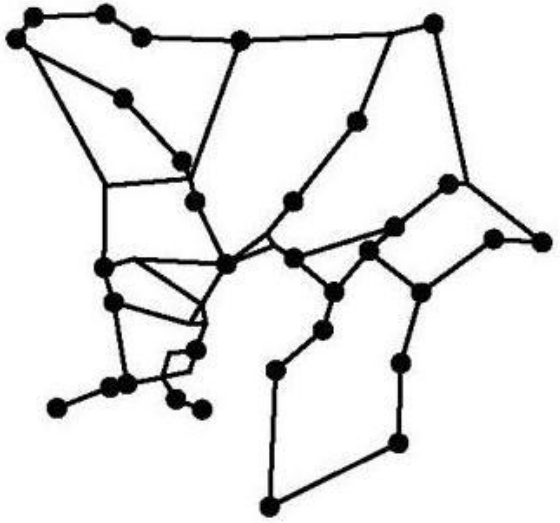
high low

Slime Mold: Rules for Biologically Inspired Adaptive Network Design

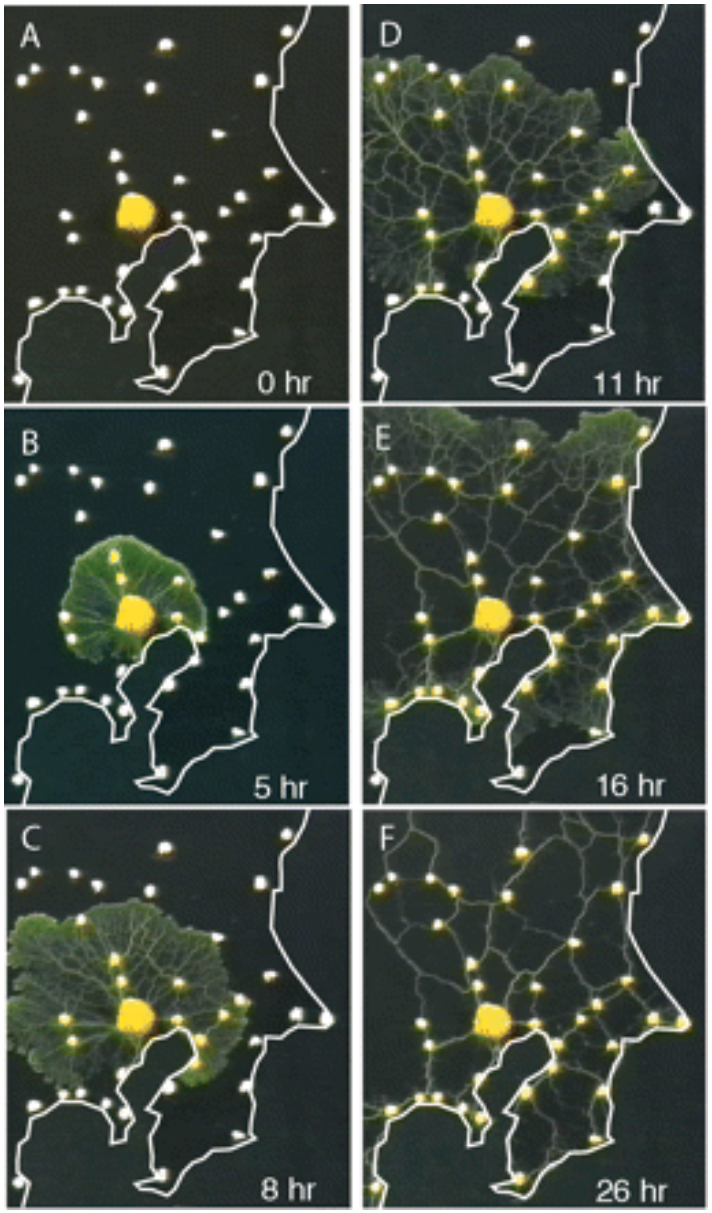
Slime mold network



Actual Tokyo railway network

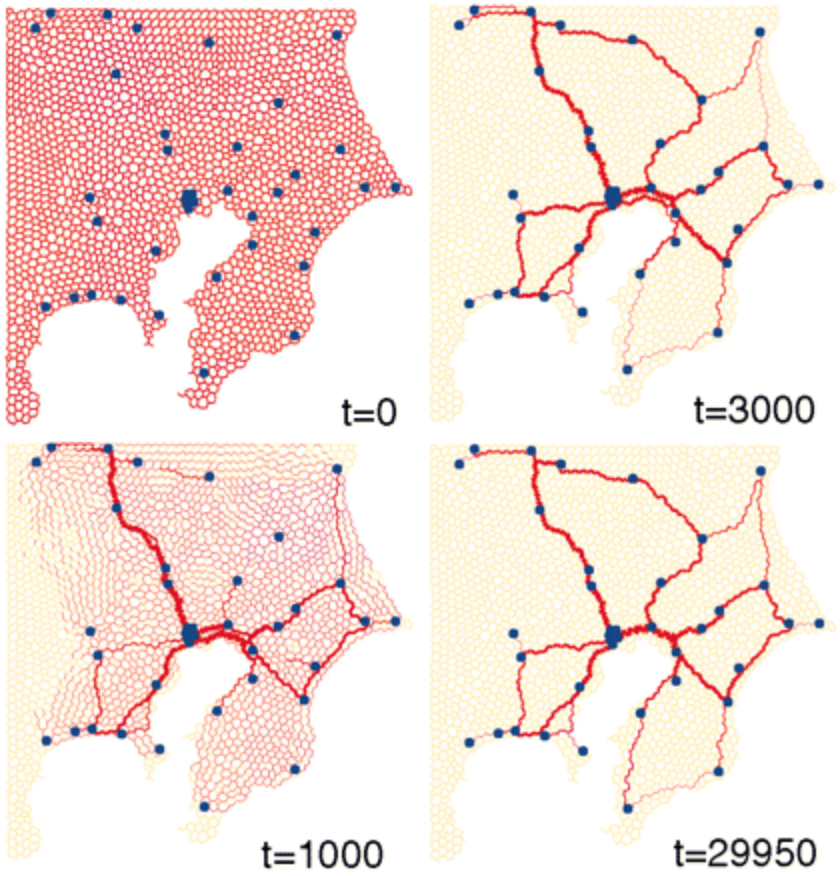


Tero et al. *Science* 2010


A
0 hr
D
11 hr
B
5 hr
E
16 hr
C
8 hr
F
26 hr

Network design

- At each iteration select two random points
- One acts as a food source, the other as the sink
- Compute flux between them based on all other points / tubes in the graph



Summary

1. We can reproduce the adaptive network of the true slime mold.
2. "*Physarum Solver*" can find the shortest path.

1. What about multiple food sources?