



How Bacteria Form 3d Structures

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Aim

How biological cells form complex spacial structures is one of the most fundamental question in biological physics. In this project the spacial organisation of surface growing E.coli (Escherichia coli) colonies on agarose was studied, aiming at testing a mathematical model that could describe it and understanding its nature.

Background

Previous research shows that a layer structure like a 3d wedding cake is formed.

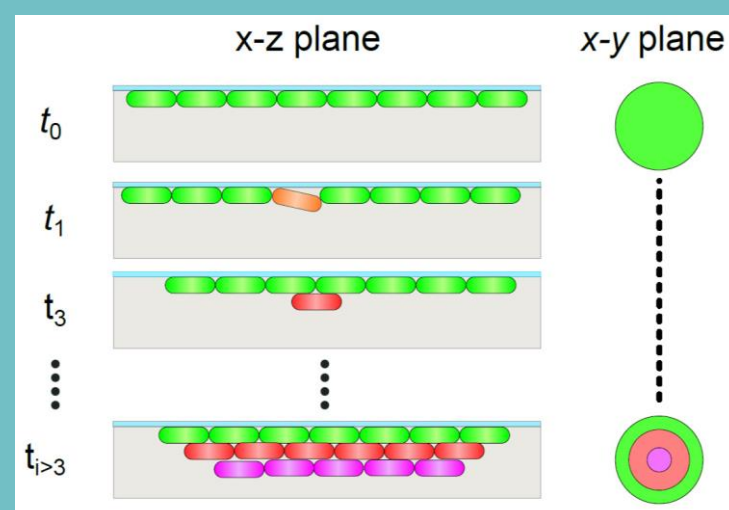


Fig. 1 [1]: schematic map of the layered structure.

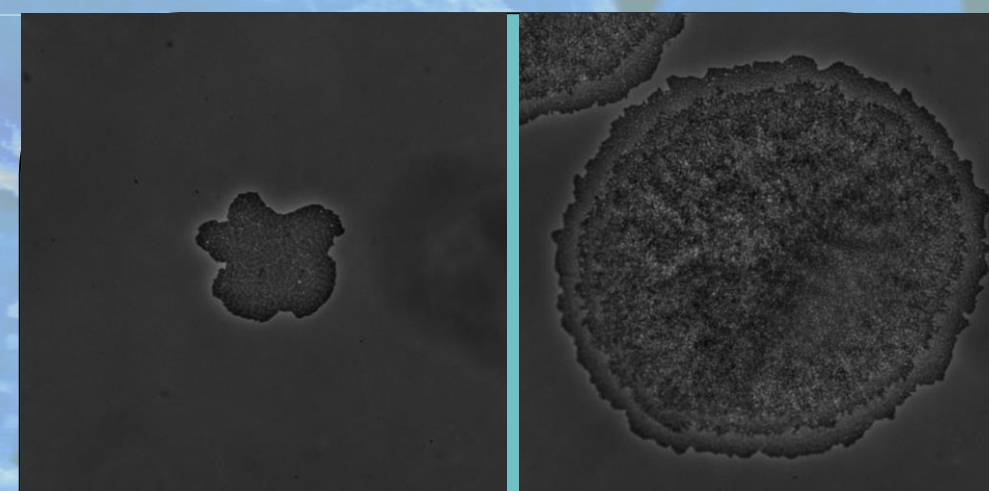


Fig. 2: Top view of the bacteria colony growth. Layers clearly observable. The radius of the 1st, 2nd and some 3rd layers versus time were obtained.

Theory

The population of bacteria grows exponentially: $N(t) = N(0)e^{\lambda t}$, which is linear under logarithmic scale: $\log(N(t)) = \log(N(0)) + \lambda t$. Assuming that the total population is not affected and there are transition $k_1(t)$, $k_2(t)$ between the three layers, the model that the growth follows coupled differential equation can be tested by finding the linear relation.

Result

Code was written in Python to process and plot the data.

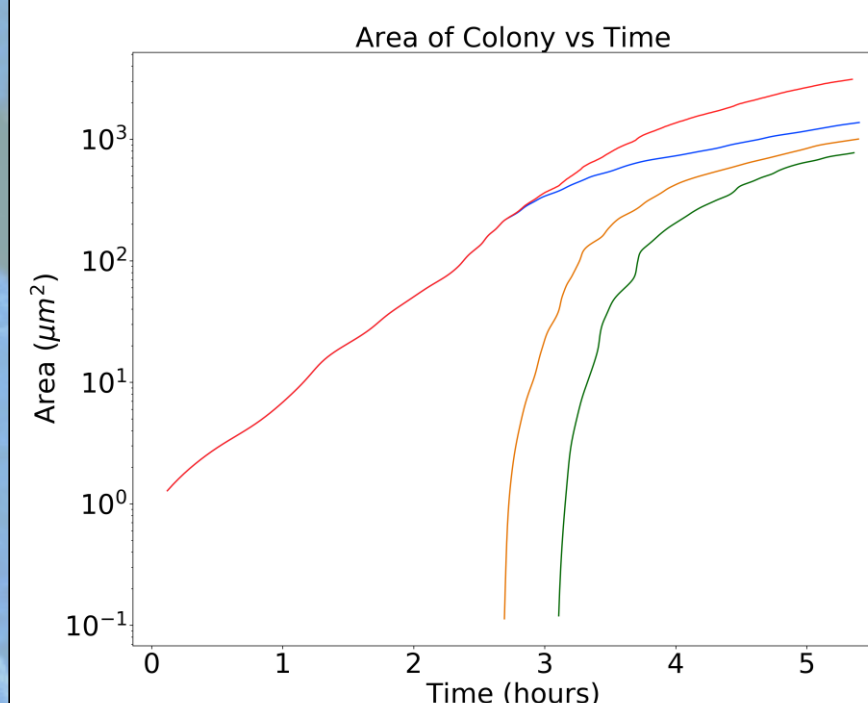


Fig. 3: Example of the area of all three layers versus time. The blue line is the 1st layer (the linear part is overlapped with the red line), the orange and green are the 2nd and 3rd layers. The red line is the total area. There is indeed a linear relation before the second layer shows up, and the linear part for the total area continued. The eventual bend may indicate structure deeper than 3rd layer or unknown influencing factors.

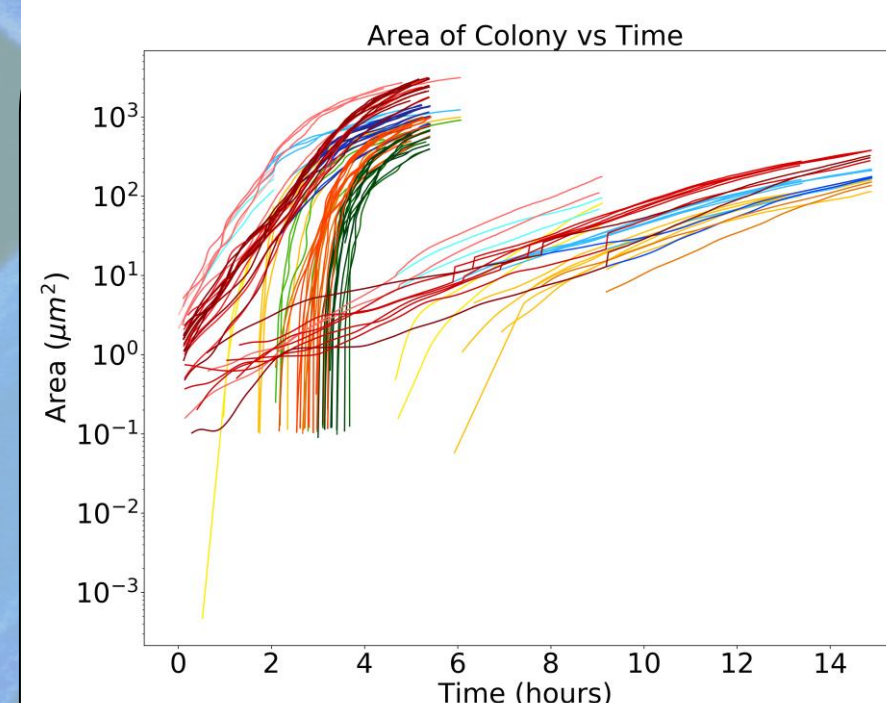


Fig. 4: The result for all 34 data files obtained from experiment agrees with the description of the model.

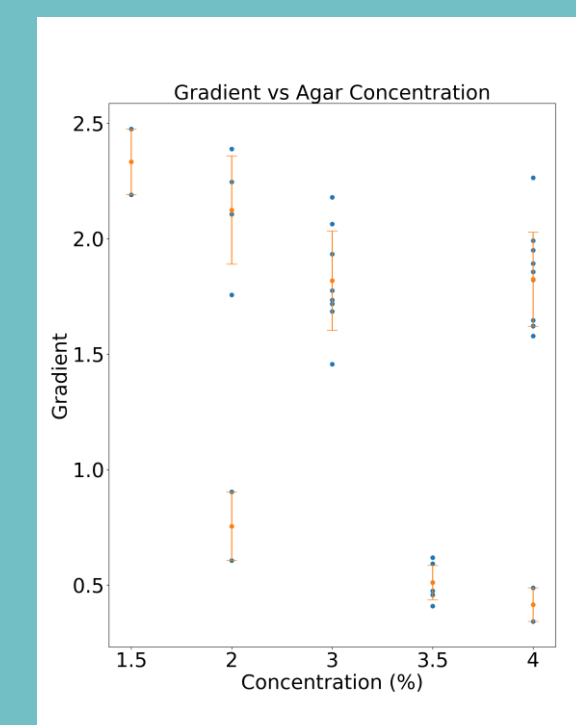


Fig. 5: The gradient of the linear part is related to the concentration of agarose.

[1] Diarmuid Padraig Lloyd. *Microscopic studies of surface growing bacterial populations*. 2015, p. 185. url: <http://hdl.handle.net/1842/10509>.
[2] Background picture from web.