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Macroscopic Growth of Bacteria Precisely Follows The Solution of the Diffusion Equation with Boundary Conditions

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Abstract:- We provide an experimental proof showing that the macroscopic exponential growth of bacteria on a delimited 2D planar surface follows precisely the same solution of the heat diffusion equation with the source / sink term and the prescribed boundary conditions.

The B-chains previously used successfully in solving the heat equation can be applied to solve the complicated PDE resulting from the growth of bacteria.

The in-depth study of experimental microbiology and the study of theoretical mathematical physics are essential to reveal more characteristics of the growth of bacteria in the bounded 2D and 3D geometric space.

I. INTRODUCTION

There are many articles explaining the growth and decay of bacteria on a microscopic level that is inspecting the time variable only but not its propagation in a macroscopic space.

To our knowledge, there are only experimental and theoretical studies on the growth / decay in the number of bacterial cells n in the time domain n = n (t).

this is probably the first rigorous test aimed at finding a relationship between the macroscopic experimental bacterial spatiotemporal growth observed in microbiology laboratories n (x, t) and the theoretical spatiotemporal mathematical PDE in mathematical physics, i.e. say combining microbiology and physical mathematics in a rigorous collective study.

Bacterial microbes are single-celled microorganisms lacking a nuclear membrane, metabolically active and dividing by binary fission. they are a major source of disease, medicine and food.

Bacterial growth is the proliferation of bacteria into two daughter cells, in a process called binary fission. Provided that no event occurs, the resulting daughter cells are genetically identical to the original cell. Therefore, exponential bacterial growth occurs.

Bacterial colonies progress through four main phases of growth: the lag phase, the log or exponential phase, the stationary phase and finally the death or decay phase.

The exponential growth, which varies among bacteria, is controlled by many environmental conditions such as temperature, humidity, oxygen content, acidity and by the nature of the bacterial species itself.

Surprising enough, the macroscopic growth of bacteria on food surface follows the resolution of the mathematical diffusion equation with subscribed boundary conditions which is the subject of this article.

II. THEORY AND EXPERIMENTAL RESULTS

A. The theoretical vision of the subject

A recent theoretical study [1] proposed that the spatiotemporal bacterial growth / decay, n (x, t) follows the same trajectory as that of the partial differential heat diffusion equation, i.e. ,

∂n (x, t) ∂t = D∂2n (x, t) ∂x2 + r n (x, t) (1 - n (x, t)) / k . . . . (1)

In normal conventions.

In many real-world scenarios, including infections, bacterial populations spread through 2D and 3D configuration space. This process could be modeled using the Fisher-Kolmogorov equation. [1]

However, there is no analytical solution for the general case of the diffusion equation 1 or numerical solution in the 2D/3D space of Nabla ^ 2 especially when the boundary conditions 2D / 3D and the source / sink term interact.

Concerning the theoretical aspect which is the mathematical solution of equation 1, we propose to apply the so-called matrix chains B successfully used in the heat diffusion equation with fixed Dirichlet boundary conditions [2] and also with dissipative conditions at the limits of free absorption [3].

B. The experimental vision of the subject

We performed an experiment with the macroscopic growth of bacteria on flat surfaces of high quality Egyptian bread maintained at 4 centigrade, pH of 7 with NP air and humidity.

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We found that the macroscopic growth of bacteria follows the mathematical solution of the PD diffusion equation 1, Fig. 1 with the actual square or circular BC prescribed.

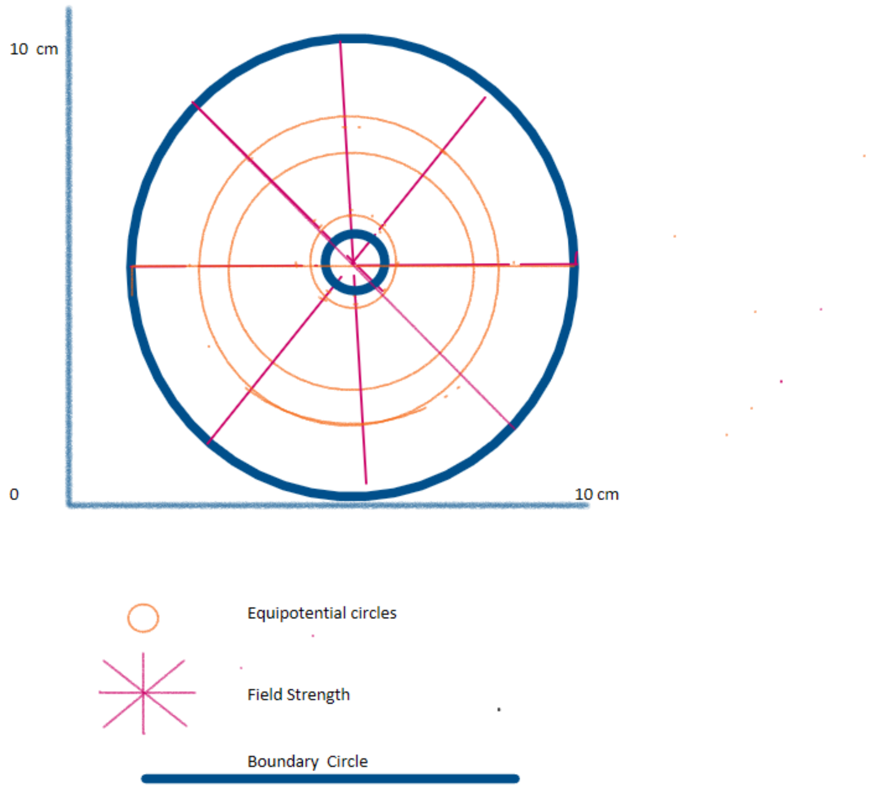

Fig. 1:- Mathematical solution for the 2D diffusion equation with circular boundary conditions.

Below is the photo showing the experimental results of the case for two concentric circles of bacteria 2.5 and 10 centimeters in diameter.

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Fig. 2:- Macroscopic growth of bacteria.

7 days Growth of bacteria on a flat food surface (high quality Egyptian bread) maintained at 4 degrees Celsius with a pH of 7, normal air and humidity.

The analogy between Fig. 2 and Fig. 1 is obvious.

Fig. 3:- The macroscopic death phase of the bacterial experiment of Fig. 2.

Three weeks decay of bacteria on a flat food surface (high quality Egyptian bread) maintained at 4 degrees Celsius with a pH of 7, normal air and humidity

Note that macroscopic shrinkage and drying in rigor mortis propagates in the opposite direction to the growth phase.

III. CONCLUSION

The current article is a small step on a long road.

It shows that the macroscopic exponential growth of bacteria follows the spatiotemporal partial differential diffusion equation with boundary conditions.

We propose that a more in-depth study of experimental microbiology and a theoretical study of mathematical physics is important to reveal more features of bacteria growth in 2D and 3D geometric space with boundary conditions.

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