Analyzing the effect of body temperature variation in maturation response time of B lymphocytes

Arthur M. Guimarães, Glauber I. F. de Carvalho
arthurmaxs8@gmail.com,glauber.inocencio@gmail.com
Federal Institute of Paraíba IFPB
João Pessoa/PB , Brazil

Manuella D. C. Silva Cruz, Fernanda S. Lima
manuelladcsilvacruz@gmail.com,limas.fernanda99@gmail.com
Federal Institute of Paraíba IFPB
João Pessoa/PB , Brazil

Carlos Danilo Miranda Regis
danilo.regis@ifpb.edu.br
Federal Institute of Paraíba IFPB
João Pessoa/PB , Brazil

Michael Taynnan Barros
michael.taob@gmail.com
TSSG, Waterford Institute of Technology
Co. Waterford, Ireland

ABSTRACT

This paper presents a preliminary analysis of how the body temperature conditions, such as hypothermia and hyperthermia, influences the response time of the maturation process of Th2 cells to B lymphocytes while receiving IL-4 molecules from transmitting basophil cells.

CCS CONCEPTS

• **Computing methodologies** → **Molecular simulation**.

KEYWORDS

Immune system, advection-diffusion-based molecular communication, Basophils, Lymphocytes B

ACM Reference Format:
Arthur M. Guimarães, Glauber I. F. de Carvalho, Manuella D. C. Silva Cruz, Fernanda S. Lima, Carlos Danilo Miranda Regis, and Michael Taynnan Barros. 2019. Analyzing the effect of body temperature variation in maturation response time of B lymphocytes. In *The Sixth Annual ACM International Conference on Nanoscale Computing and Communication (NANOCOM'19), September 25–27, 2019, Dublin, Ireland*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3345312.3345494

1 INTRODUCTION

The Internet of Bio-Nano Things has allowed innovative solutions to a numerous range of scientific problems. In medical and healthcare domains, it brings the opportunity to use and mix synthetic biology, molecular communications and nanobiotechnology to develop novel treatments and diagnosis of human diseases. In the human body, the first system that deals with diseases are the immune system within organs, tissues, cells and molecules. The lymphocytes and other defence cells, like white blood cells, resemble nodes of a network that synthesizes molecules and exchange information. These molecules are generally hydro proteins called cytokines and act as a stimulus to differentiation, maturation and activation of lymphocyte cells. A diverse number of cells can produce this stimulus, however, the source of cytokines that control the differentiation of T helper lymphocytes (Th2) into B-lymphocytes in vivo is not completely well understood. Soko et. al. [6] has shown that the basophils, a white blood cell, are capable of producing the inducing cytokines, as interleukin 4 (IL-4), to differentiate Th2 in-vivo. On the other hand, the human body is very sensitive to a lot of environmental factors. Temperature variation, for example, can cause and affect directly the human body systems response, affecting internal molecular communication processes. This paper presents a quantification analysis of how the body temperature variation affects the maturation response time of B-lymphocytes. Our study considers B-lymphocytes maturation from Th2 after induction of IL-4 transmitted from basophils present in the blood. Based on this, it is essential to use molecular communications theory to study how the hypothermia and hyperthermia into capillary vessels affect this maturation process.

From a molecular communications theory perspective we model the basophil as the transmitter, Th2 cells are the receivers and the IL-4 is the information that goes through the blood as the carrier and channel respectively. We focus our analysis in the micro-scale cardiovascular system, thus we decide to consider the capillary vessel. They are the smallest channel in the cardiovascular system and they have viscosity and environmental parameters defined by [1]. In a capillary vessel, the motion of cells and molecules propagate through their spontaneous diffusion motion in a fluid medium [4]. We model this process as an advection-diffusion-based molecular communications system, and we aim to measure the number of information detected and delay response that takes to basophil cells to send information to Th2 cells under the conditions of hypothermia and hyperthermia in the blood capillary vessel, which is directly linked to their maturation response.

2 METHODS

Most of the studies regarding the random motion of particles in a fluid use the Brownian motion as base [2]. Einstein was the first to introduce a method to analyse this phenomenon in his thesis[5]. In his method, he achieves the diffusion coefficient of a particle in the medium by the equation

NANOCOM'19, September 25–27, 2019, Dublin, Ireland

ACM ISBN 978-1-4503-6897-1/19/09…$15.00
https://doi.org/10.1145/3345312.3345494

$$D = \frac{k_B T}{6\pi\gamma\alpha} \quad (1)$$

.

where k_B is the Boltzmann constant, T is the temperature in the Kelvin scale, γ is the medium viscosity and α is the molecule radium. This coefficient D is combined with the simulation time to define the point that the particle will occupy in the next instant of time, giving the coefficient $k = \sqrt{2 * D * t}$. The particle position $p(x, y)$ is calculated for each time t as a decreased cumulative sum of several random points given by

$$p_n(x, y) = (k * rand(x) + f, k * rand(y)) \quad (2)$$

$$p(x, y) = \sum_{n=1}^{N} p_n + p_{n-1} + \ldots + p_1 \quad (3)$$

where f is the variable flow that means how much blood circulate for the capillary vessel for an instant of time. For our analysis, we consider the motion in a two-dimensional space (x, y). We randomly deployed initial positions of cells within the capillary vessel space. The initial position of the information (IL-4) is the membrane of the basophil, mathematically it means that we positioned them in the surface of the transmitter cell. The values used for the radius of the particles we obtained from [2], basophils and lymphocytes have 10 and 12 m of radium respectively, and IL-4 has a radius of 1.8 nm. To calculate if the absorption of IL-4 for a Th2 has occurred we used the Euclidian distance formula

$$d_{IR} = \sqrt{(X_R^2 - X_I^2) + (Y_R^2 - Y_I^2)} \quad (4)$$

A collision or absorption of IL-4 occurs when the distance between the receptor R to the information is less or equal than the sum of their radius. Our method considers both collisions types, receptor colliding with information or the opposite. When an information particle achieves a receiver, the colour of receptor Th2 changes. It represents that the achieved Th2 receive the IL-4 and becomes a B-lymphocyte. If a particle receives the information more than once it won't affect our system since real biochemical models are also indifferent to multiple particle reception. Our study was conducted with 25 basophils, 30 of Th2 cells and one IL-4 for each basophil, obtained to represent the proper proportion between particles, as discussed in [3, 5].

3 RESULTS AND CONCLUSIONS

We aim to study the temperature variation as three different scenarios (normal, hypothermia and hyperthermia) to analyze the absorptions of the molecules by Th2 cells in capillary vessels. For our analysis, we used the 309.65K for normal temperature, 307.15K for hypothermia and 312.65 for hyperthermia, which was extracted from [1]. In Figure 1, we show the number of information molecule achieve the receptor in an interval of 1 second. We observe that the hyperthermia scenario has a slightly higher number of molecules absorbed by receptors than when the body temperature is at a normal level, with the hypothermia scenario presents the lowest values.

Figure 2 shows how temperature affects the motion of molecules during an interval time of 10 seconds. The receptor cells are released

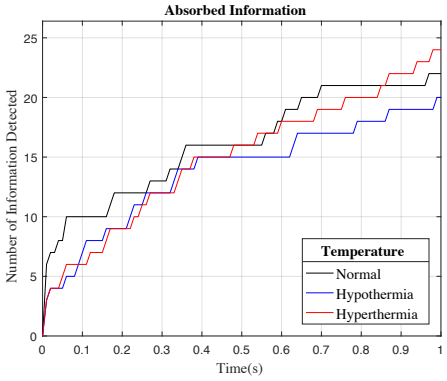

Figure 1: Amount of absorbed information for time.

in a distance of ten times its diameter from the transmitter. During this time is possible to observe that the reception will occur just after an initial time and that this time differs being less for hypothermia scenario and slow to hyperthermia.

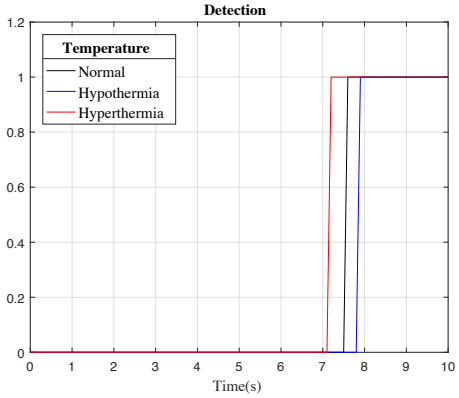

Figure 2: Time for initiate the detection.

Our analysis shows that hyperthermia can affect the body with lower delay and higher information rate as a way to accelerate the assimilation of IL-4 by the Th2 cells differentiate it into lymphocyte B. We are further interested in understanding and quantifying how the temperature influences the maturation process of B-lymphocytes permit the development of medicinal methods to accelerate the humoral immune response.

REFERENCES

[1] R Fahraeus and R Lindqvist. 1931. The Viscosity of the Blood in Narrow Capillary Tubes. In *American Journal Physiology*, Vol. 96. 562–568.
[2] L Felicetti, M Femminella, and G Reali. 2011. A simulation tool for nanoscale biological networks. In *NanoCommunication Networks*, Vol. 3. 2–18.
[3] AD Keegan. 2000. *Cytokine reference: IL-4* (1 ed.). 1, Vol. 1. Academic Press, San Diego.
[4] M Pierobon and IF Akyildiz. 2010. A physical end-to-end model for molecular communication in nanonetworks. In *IEEE Journal on Selected Areas in Communications*, Vol. 28(4). 602–611.
[5] JM Silva and JAS Lima. 2007. Four approaches to the brownian motion. In *Rev. Bras. Ensino FÃŋs*, Vol. 29(1). 25–35. https://doi.org/10.1590/S1806-11172007000100007
[6] CL Sokol, G.M. Barton, AG Farr, and R Medzhitov. 2008. A mechanism for the initiation of allergen-induced T helper type 2 responses. In *Nature Immunology*, Vol. 9. 310–318.