ISSN: 1391-8796
Proceedings of
2nd Ruhuna International Science & Technology Conference
University of Ruhuna, Matara, Sri Lanka
January 22-23, 2015

A stochastic model for T-cell-APC system based on Random Energy Model

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A simple stochastic model for the interactions between T-cell and Antigen Presenting Cell (APC) system is proposed with a major concern on the effect of T-cell receptor cluster formation on T-cell activation. We consider a 'sample space' {-1, 1} of interaction events, where '-1' (respectively'1') corresponds to an unfavorable (respectively favorable) interaction between the T-cell and APC and propose the Hamiltonian model for the binary sequences of interactions between T-cell and APC system. The specific free energy of the model with respect to a control parameter called 'generation time' is calculated via numerical Monte-Carlo simulations. We report the effects on the specific free energy of the strength of the interactions between clusters, that of the number of clusters, of the standard deviation of the distribution of energies associated with the interactions between the T-cell and APC, and also that of the generation time. We cannot see any discontinuity in the free energy with respect to the parameter, $\widetilde{T}$ - generation time. However, at $\widetilde{T}$ (= 0.163) we can notice a change in the derivative which shows that the free energy remains constant for $T \geq \widetilde{T}$. The sustained interaction between the T-cell and the APC leads to intracellular signaling mechanisms that would ultimately cause the activation of the T-cell. The activated T-cell is no longer the same as the non-activated or a naive T-cell; it would undergo substantial conformational/ geometrical changes as well as internal changes that occur in the nucleus of the T-cell to activate the gene regulation as transcriptional factors leading to launch various activation functions. Hence, the system of interactions between T-cell and the APC evolves into a new state, which we propose here to explain via phase transitions in the Random Energy Model.

Key words: Random energy model (REM), T cell receptor (TCR), Antigen presenting cell (APC), Peptide Major histocompatibility complex (pMHC), Specific Free energy (SFE), Monte-Carlo Simulations.

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