Dynamics of single cell crawling: stick-slip movement

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Cell movement is a complex phenomenon brought about by several physical and biological processes [1]. Crawling is the most common form of movement for motile cells. There is a cyclic sequence of processes a cell must go through for a single crawling motion. The first among these processes is the protrusion of the leading edge of the cell. This is generally brought about by the polymerization of actin filaments towards the cell membrane. The next step in the chain of processes leading to motility is the formation of focal adhesion complexes between the cell and the substrate. Focal adhesions are basically an assembly of proteins that form the connection between the cell and substrate. These focal adhesions help the cell to anchor the protrusion while the retrograde flow of the actin filament takes place. The final step in motility is the translocation of the cell body and the rear of the cell. There are some phenomena which are observed during cell crawling. These include Stick-Slip dynamics [2] which is a process consisting of two different segments the 'stick' phase in which the formation of new focal adhesion takes place and the 'slip' phase where all the focal adhesions are broken off due to increased stress on them. There are few experimental studies which found that increase in force on the focal adhesion complexes promote their growth in the direction of applied force [3].

We propose a theoretical model consisting of a large number of free receptors diffusing within the cell cytoplasm. A large number of ligands are also present in the Extra-Cellular Matrix which bind with the diffusing open receptors to form closed bonds on the actin filament. The ligand-receptor molecular bond formation represents focal adhesion formation between cell and extracellular matrix. The dynamics of the open and closed receptors are described by a pair of coupled reaction-diffusion equations. The closed receptors are not able to diffuse freely unlike their open counterparts but they can only move via their drift velocity, which is basically the retrograde flow velocity of the actin filament, since they are attached to it. The open and closed receptors interchange between their states (to form closed or open bonds) with two pre- defined rates which are dependent on force. The dissociation rate of the closed bonds is taken to be exponentially increasing with force following Bell's Model [4]. The association rate of the open receptors to form closed bonds is also considered to be force dependent. We present some preliminary results of our theoretical model and compare it's prediction with recent experimental findings.

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