Viscoelastic Properties of Rat Fibroblast Cells Using Atomic Force Microscopy (AFM)

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Cellular processes like motility, morphogenesis, and differentiation are heavily governed by the physical properties of the cell. For example, cellular stiffness is a primary indicator of the metastatic potential of malignant cells in cancer. Atomic Force Microscopy (AFM) can be used to measure the force response of a cell by pushing on the cell with a microcantilever. In order to determine the correlation between cytoskeletal activity and the mechanical behavior of a cell, stress tests were performed on dead and live rat fibroblasts, because the cytoskeleton is static in a dead cell and dynamic in a live cell. Physical parameters of the cell like modulus of elasticity (cellular stiffness) and relaxation times were extracted by fitting a newly developed viscoelastic model to the force vs. time data. In previous studies, a nonlinear elastic model was used, thus providing an inaccurate picture of a cell's force response. With the new viscoelastic model, energy loss in the interaction between the AFM tip and the sample was accounted for. In live cells, energy loss levels were higher than in dead cells, and force curvature was steeper, especially at higher strain rates. Also, live cells relaxed significantly faster than dead cells. This can be attributed to a reorganization of actin filaments in the dynamic cytoskeleton, which aids the relaxation process in live cells. The ability of the new viscoelastic model to find cell relaxation times opens the door for many future AFM experiments, which could give deeper insights into the mechanical behavior of metastatic cells in cancer.

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