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Quantitative nano-mechanics of biological cells with AFM

IGOR SOKOLOV[1], Tufts University

The importance of study of living cells is hard to overestimate. Cell mechanics is a relatively young, yet not a well-developed area. Besides just a fundamental interest, large practical need has emerged to measure cell mechanics quantitatively. Recent studies revealed a significant correlation between stiffness of biological cells and various human diseases, such as cancer, malaria, arthritis, and even aging. However, really quantitative studies of mechanics of biological cells are virtually absent. It is not even clear if the cell, being a complex and heterogeneous object, can be described by the elastic modulus at all. Atomic force microscopy (AFM) is a natural instrument to study properties of cells in their native environments. Here we will demonstrate that quantitative measurements of elastic modulus of cells with AFM are possible. Specifically, we will show that the "cell body" (cell without "brush" surface layer, a non-elastic layer surrounding cells) typically demonstrates the response of a homogeneous elastic medium up to the deformation of 10-20%, but if and only if a) the cellular brush layer is taken into account, b) rather dull AFM probes are used. This will be justified with the help of the strong condition of elastic behavior of material: the elastic modulus is shown to be independent on the indentation depth. We will also demonstrate that an attempt either to ignore the brush layer or to use sharp AFM probes will result in the violation of the strong condition, which implies impossibility to use the concept of the elastic modulus to describe cell mechanics in such experiments. Examples of quantitative measurements of the Young's modulus of the cell body and the cell brush parameters will be given for various cells.

[1]Address when submitting: Clarkson University, Potsdam, NY 13699