MECHANICS OF BIOLOGICAL TISSUES AND INTERNAL VARIABLES

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Mechanics of biological tissues is closely related to mathematical modeling of biological processes [1]. The knowledge of the theory of continua, biochemistry, thermodynamics, etc. should be interwoven into a whole bearing in mind biological functions of tissues. One of the characteristic features of such modeling is accounting for hierarchies - structural hierarchies (in terms of continua - microstructures) and functional hierarchies (hierarchy of physiological processes). Functional hierarchies can be analysed by using a comparatively novel concept of continuum mechanics - the concept of internal variables [2]. This concept makes a clear distinction between observable (possessing inertia) and internal (not possessing inertia) variables. The features of biological tissues and processes are best characterised by generalising the concept of internal variables to reflect multiple scales in functional hierarchy [3].

In this paper we present first a brief overview on the ideas of internal variables and the focus on application in biomechanics/biophysics. A typical example of the internal variables is explaining the nerve pulse propagation where the action potential along the nerve fiber is actually governed by the ion currents which clearly play the role of internal variables [4].

The idea of hierarchical internal variables is elaborated in more details for modeling the cardiac contraction [3]. The structure of a myocardium clearly demonstrates the structural hierarchy from muscle bundles to sliding filaments. The functional hierarchy involves an observable variable - active stress - and the three-level internal variables. The first level internal variable according to the Huxley model includes the relative amount of cross-bridges which produce force. The second level internal variable includes the activation parameter (the sum of all activated cross-bridges). The third level internal variable includes the concentration of calcium ions responsible for triggering the motion of cross-bridges. All internal variables are governed by their own kinetic equations and influence the observable variable through the hierarchy starting from the lowest level. This idea is realized by numerical simulation of cardiac contraction and tested against various physiological experiments [5].

References

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