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COMPOSITE SMEARED FINITE ELEMENT – A REVIEW OF ADVANCES IN MULTISCALE MODELLING OF COUPLED PHYSICAL FIELD AND MECHANICS OF BIOLOGICAL SYSTEMS

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We have recently developed a composite smeared finite element (CSFE) for physical fields in biological systems, initially formulated for diffusion [1], then generalized to any gradient driven physical field [2], further applied to ionic transport and electrophysiology and coupled to heart mechanics [3]. The concept of the smeared fields was extended to mechanics in general, outlined in [2].

The basic idea of this methodology consists in partitioning the volume of the CSFE into domains according to the volumetric fraction of each constituent of a composite biological medium, and coupling the physical fields by using 1D connectivity elements (which are fictitious as they do not occupy the space) at each FE node. The domains in the CSFE also include the 1D transport in tissue, as within capillaries, lymph vessels or neural fibres. Here, the 1D transport is transformed into a continuum form by formulating transport tensors. In each of the continuum domains of the CSFE the corresponding constitutive laws are implemented. On the other hand, the connectivity elements represent the biological barriers, as capillary walls or membranes of cells or organelles, with their transport properties.

In this review we summarize the basic concept of the CSFE and illustrate its applicability to multiscale problems of biological systems, as drug delivery within liver with tumors, or electrophysiology of the heart coupled with mechanical response of the heart wall deformation – blood flow within the heart.

In conclusion, the introduced smeared FE modelling offers a methodology which, with the corresponding software for generation of models from images and clinical investigations, can be implemented to real large biological systems as heart or other organs.

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