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Relating biophysical properties across scales: implications for early development and applications for tissue engineering[1]

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A distinguishing feature of a multicellular system is that it operates at various scales and levels of organization. Genes set up the conditions for physical mechanisms to act, in particular to shape the developing organism and establish its material characteristics. As development continues the changes brought about by the physical processes lead to changes in gene expression. It is through this interplay that the organism acquires its final structure and composition. It is natural to assume that in this multi-scale process the smaller defines the larger. In case of biophysical properties, in particular, those at the subcellular and cellular level are expected to give rise to those at the tissue level and beyond. Indeed, the physical characteristics of tissues vary greatly in physical properties: blood is liquid, bone is solid. In between these extremes lie most of the organs and tissues with intermediate viscoelastic properties. However, a blood cell is not the same as a liquid drop and a single bone-forming cell itself is not a solid. Little is known on how tissue and organ level properties are related to cell and subcellular properties. We introduce a novel combined theoretical-computational-experimental framework to address this question. The basis of our approach is a representation of a cell by a network of interacting 'organelles' (i.e. modules) with cell-specific properties. Cells form tissues and eventually organs through interactions either directly with each other or through secreted substances. The experimental and theoretical inputs of the formalism are inseparable: it cannot even be set up without one or the either. The method can serve as the basis for "computational tissue engineering".

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