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Diane Peurichard - Mathematical modeling of tissue morphogenesis and regeneration

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In this talk, we investigate the mechanisms by which organs acquire their functional structure, realize its maintenance over time and rebuild their architecture after injury. We do this by means of two-dimensional Individual Based Models (IBM) of interacting cells and extra-cellular-matrix fiber elements. The mechanical model first shows that the emergence of organized structures could be explained by simple mechanical interactions between the cells and the collagen fibers. Our assumption is that the fiber network resists the pressure induced by the growing cells and forces them to regroup into clusters. Reciprocally, cell clusters force the fibers to merge into a well-organized network. When applied to adipose tissues, the model produces structures that compare quantitatively well to the experimental observations and seems to indicate that cell clusters could spontaneously emerge as a result of simple mechanical interactions between cells and fibers and surprisingly, vasculature is not directly needed for these structures to emerge. In the second part of the talk, we extend this model to account for mechanisms of tissue repair after injury, and use it to explore the mechanisms responsible for adipose tissue regeneration. The model successfully generates regeneration or scar formation as functions of few key parameters, and seems to indicate that the fate of injury outcome could be mainly due to extra-cellular (ECM) matrix rigidity. Altogether, these studies point to the essential role of mechanics in tissue structuring and regeneration, and bring a comprehensive view on the role of ECM crosslinking on tissue architecture emergence and reconstruction.