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Structure and Swelling Behavior of Cartilage

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Cartilage is a complex tissue composed of a gel-like matrix containing primarily chondrocytes, collagen fibrils, proteoglycans (PGs), and glycosaminoglycans. Collagen type II fibrils form a resiliant network that restrains the osmotic forces caused by the charged PGs. The most abundant PG in cartilage is the bottlebrush-shaped aggrecan. With age and disease, both the concentration and composition of the PGs are altered and its large-scale structure degrades. The mechanism by which cartilage extracellular matrix components contribute to the biomechanical properties is poorly understood. It is known that a decrease in the osmotic pressure is associated with degenerative conditions such as osteoarthritis. To improve our understanding of the pathogenesis of cartilage degeneration and to develop therapeutic strategies for its treatment requires knowledge of the physico-chemical interactions among the constituents of cartilage extracellular matrix. We developed a multiscale experimental approach to study the structure (morphology) and thermodynamic properties of biopolymer assemblies as a function of the length scale (spatial resolution) by combining macroscopic osmotic swelling pressure measurements, microscopic imaging methods and high-resolution small-angle scattering techniques. Imaging by the Atomic Force Microscope (AFM) allows us to visualize the macromolecules and their assemblies on the surface of a suitable substrate at a microscopic and sub-microscopic scale. Small-angle neutron scattering (SANS) and small-angle X-ray scattering (SAXS) enable the investigation of the organization of biopolymer molecules over a wide range of length scales and provides information on structural changes in response to changes in the environmental conditions (e.g., ion concentration, ion valance, pH, temperature). In regenerative medicine, such knowledge is essential to design patient-specific implants tailored to match simultaneously the biomechanical properties and biochemical and molecular compatibility of the replaced tissue.