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Elasticity and Piezoelectricity in Biological Systems on the Nanoscale: From Bones to Butterflies

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Functional properties of biological systems are determined by an intricate set of mechanical and electromechanical interactions on the length scales that span several orders of magnitude: from macro to nano. Electromechanical coupling is a universal property of biological systems that was first discovered when Luigi Galvani observed the effect of "animal electricity" in a frog leg. Understanding the inherently intertwined mechanical and electromechanical properties, such as elasticity and piezoelectricity, in the living systems can provide an insight into the functionality of biomaterials and understand the biological relevance of these properties. Here, we present a scanning probe microscopy based approach for elastic and electromechanical imaging and spectroscopy of biological systems – from imaging the elasticity map in butterfly wings to differentiation of elastic and piezoelectric properties in enamel and dentine layers of human tooth to measuring the electromechanical response of a single collagen molecule. This allows us to repeat Galvani's experiment on the nanoscale – more than two centuries later and with a million times higher resolution.

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