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Environmental properties set cell mechanics and morphology

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Many cell types are sensitive to mechanical signals that are produced either by application of exogenous force to their surfaces, or by the resistance that their surroundings place on forces generated by the cells themselves. Cell morphology, motility, proliferation, and protein expression all change in response to substrate stiffness. Changing the elastic moduli of substrates alters the formation of focal adhesions, the assembly of actin filaments into bundles, and the stability of intermediate filaments. The range of stiffness over which different primary cell types respond can vary over a wide range and generally reflects the elastic modulus of the tissue from which these cells were isolated. Mechanosensing depends on the type of adhesion receptor by which the cell binds, and therefore on both the molecular composition of the extracellular matrix and the nature of its link to the cytoskeleton. Many cell types can alter their own stiffness to match that of the substrate to which they adhere. The maximal elastic modulus that cells such as fibroblasts can attain is similar to that of crosslinked actin networks at the concentrations in the cell cortex. The precise mechanisms of mechanosensing are not well defined, but they presumably require an elastic connection between cell and substrate, mediated by transmembrane proteins. The viscoelastic properties of different extracellular matrices and cytoskeletal elements strongly influence the response of cells to mechanical signals, and the unusual non-linear elasticity of many biopolymer gels, characterized by strain-stiffening, leads to novel mechanisms by which cells alter their stiffness by engagement of molecular motors that produce internal stresses. Cell cortical elasticity is dominated by cytoskeletal polymer networks and can be modulated by internal tension. Simultaneous control of substrate stiffness and adhesive patterns suggests that stiffness sensing occurs on a length scale much larger than single molecular linkages and that the time needed for mechanosensing is on the order of a few seconds.