Optoregulated force application to individual cellular receptors using molecular motors

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Mechanical force is a driving factor in guiding cell shape, migration and even gene regulation. Several methods have been developed to apply mechanical forces to cells, including micropipettes, magnetic tweezers and magnetic actuation of nanoparticles. Optical strategies for manipulating biological systems have experienced a great development in recent years, such as photoswitches and optogenetic constructs. Methods that allow for precise light-induced physical inputs to biological systems could impact studies in mechanotransduction. However, it is still challenging to develop molecular systems that can transfer light into mechanical force with molecular specificity and high spatiotemporal resolution.

We present a novel approach for applying forces to cells with molecular specificity and at molecular resolution using a light-driven synthetic molecular motor. The motor is modified with two orthogonal sets of polymer chains in its upper and bottom parts. It is immobilized on a biomaterial and contains adhesive ligands at two free ends. Upon light exposure, the molecular motor rotates and twists the entangled polymer chains, thereby applying a mechanical load to receptor-ligand complexes on the cell surface. Using Flow Force Microscopy we show that the motors are able to induce picoNewton forces. We further demonstrate the motor-induced mechanical activation of integrins in fibroblasts, leading to Focal Adhesion growth, as well as T-cell receptor activation as measured through calcium signaling.