Micro-mechanical model of muscle contraction
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At the length scale of the fiber, the response of a muscle to rapid short increments in length, which is related to the power stroke (PS), is usually described using the model proposed by AF Huxley and RM Simmons in the 1971 [1], while the slower recovery of the initial tension and the force velocity behavior, which are related to the attachment-detachment process (AD), are usually described using the model proposed by AF Huxley in the 1957 [2]. We have explored numerically the relation between the classical experiments made on the entire muscle fiber/fibrils with two recent single molecule experiments. The first one [3] is performed on a single head of myosin II attached to a large microneedle in the presence of an actin filament and shows that the myosin head can do from one to five 5.5 nm steps in one preferred direction per ATP cycle. The second experiment [4] is based on a single head of Myosin VI attached to a bead, trapped in a laser, in the presence of an actin filament. Rapid (76 microseconds) large (250 nm) displacements are imposed to the bead, revealing that the probability to switch from a weakly attached state to a strongly attached state increases when the scan is performed in the opposite direction of the natural movement of the head itself. This effect can be referred to as Strain Sensor (SS).

Defining the behavior of the muscle, at the fiber length scale, starting from these new experimental evidences, at the molecular motor scale, we are able to produce a micro-mechanical model of the muscle contraction. First we introduce a modification of the classical model of the PS [1] which allows its description in the framework of the Brownian ratchet theory. Then we describe, in this framework, a new model of muscle contraction which integrates the PS mechanism and the AD process and which is able to reproduce the experimental evidences. The behavior of the model is analyzed by a stochastic simulation of the Langevin equations associated to a population of parallel distributed myosin heads. We show that the SS effect can have an important role in the efficiency of the contraction.