To go with the flow: Molecular motors are a drag
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Appendix D

The Duty Ratio

The Molecular motors that are studied in this thesis are processive motors i.e. a single motor can walk along a filamentous tracks without dissociating from it. A simple theoretical model called the duty ratio (originally called the duty cycle [75]) was developed to determine if a motor is processive [3,76]. The duty ratio, $r$, (eq.D.1) is the fraction of time, $\tau_{on}$, a single head of a molecular motor spends bound to the cytoskeleton during the hydrolysis of a single ATP. The velocity, $V$, of a motor head equals the working stroke, $\delta$, divided by the time it spends bound to the cytoskeleton $\tau_{on}$. Moreover, as the stepping cycle is related to the ATPase rate, ATPase, the total cycle time is expected to be $\tau_{tot}=1/\text{ATPase}$. Finally, it is possible to couple the duty ratio to the number of motor heads, $N_{min}$, needed for continuous movement. Combining the above leads to the following expressions for the duty ratio [3,76]:

$$r = \frac{\tau_{on}}{\tau_{on} + \tau_{off}} = \frac{\tau_{on}}{\tau_{tot}} = \frac{\delta \text{ATPase}}{V} \approx \frac{1}{N_{min}}. \quad (D.1)$$

Assuming that both heads spend an equal amount of time in bound state, the duty ratio has to be at least 0.5 for processive motors. At lower values there will always be moments at which none of the heads will be attached, and therefore more than two heads or even an array of motors would be required. Additionally, it is known that when a single processive head moves its path distance to the next available binding site, for kinesin this can be 8 nm (Inchworm) or 16 nm (Hand-over-hand), the centre of mass of the molecule only moves the distance of a single binding site. The duty ratio is constrained by the size of the conformational changes the motor makes as well as by the cytoskeletal path. A typical value for a processive kinesin-I motor is $r=0.5$ whereas a muscle myosin motor has a duty ratio of only $r=0.01$, suggesting that a single motor head only covers a small fraction of the distance between two binding sites [76]. This means that skeletal muscle myosin is not a processive motor and thus an array of motors is needed to work in concert to generate motion.