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Microtubule bundle formation

During mitosis, microtubules form a spindle, which is responsible for the segregation of chromosomes. In yeast cells, the spindle has a rod-like structure and is made of microtubules emanating from two poles connected by cross-linking proteins. Microtubules self-organize into parallel or antiparallel bundles, depending on whether they grow from the same or two different poles and our goal here is understanding how such structures form. Our model includes thermally driven angular pivoting of microtubules around the poles and elastic forces between them mediated by cross-linking proteins, which can detach to and detach from microtubules, as well as move along them. The solutions of our model imply that the random motion of the microtubules allows them to find a their pair, while the short-range interactions caused by the cross-linking proteins align them into bundles. Parallel bundling can occur in the presence of either passive crosslinkers or plus-end directed motors, while the formation of antiparallel bundles requires minus-end directed motors. The model predicts the average bundling time, which is in agreement with our experimental measurements. Additionally, for the case of antiparallel bundle formation, the model predicts that the velocity of the microtubules gliding along each other is the same as the velocity at which the motors move along the microtubules, and this was also confirmed experimentally. In conclusion, the main contributors to the formation of microtubule bundles are angular diffusion of microtubules around the poles allowing them to come into contact and short-range forces caused by cross-linking proteins that align them.

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