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Chromosome oscillations in mitosis

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Successful cell division necessitates a tight regulation of chromosome movement via the activity of molecular motors. Many of the key players at the origin of the forces generating the motion have been identified, but their spatial and temporal organization remains elusive. In animal cells, chromosomes periodically switch between phases of movement towards and away from the pole. This characteristic oscillatory behaviour cannot be explained by the current models of chromosome positioning and congression. We perform a self-contained theoretical analysis in which the motion of mono-oriented chromosomes results from the competition between the activity of the kinetochore and chromokinesin motors on the chromosome arms. Our analysis, consistent with the available experimental data, proposes that the interplay between the aster-like morphology of the spindle and the collective kinetics of molecular motors is at the origin of chromosome oscillations, positioning and congression. It provides a natural explanation for the so-called chromosome directional instability and for the mechanism by which chromosomes sense their position in space. In addition, we estimate the in vivo velocity of chromokinesins at vanishing load and propose new experiments to assess the mechanism at the origin of chromosome movement in cell division.