The Mitotic Chromosome: an Assembly of Rigid Elastic Axes, Organized by SMC Proteins and Surrounded by a Soft Chromatin Envelope

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Although mitotic chromosomes have been observed for more than a century, their internal structure is still poorly characterized. Here we will describe the use of a novel approach based on elasticity measurements of a single chromosome for studying the organization of these objects. The approach combines measurements of both longitudinal deformability and bending rigidity of an individual chromosome. By using specially designed micropipettes, the single chromosome force-extension curve was determined. Analysis of the curvature fluctuation spectrum allowed for the measurement of chromosome bending rigidity. The data reveal that mitotic chromosomes exhibit a non-homogenous structure consisting of rigid elastic axes surrounded by a soft chromatin envelope. The chemical continuity of DNA, but not RNA, was required for the maintenance of these axes. The axes show a modular structure and the SMC proteins participate in their organization. Topoisomerase II was not involved in either the organization of the axes, or in the maintenance of the mitotic chromosomes.

A model for the assembly and the structure of the mitotic chromosome is proposed. According this model the chromosome axes are dynamic structures which assemble at the onset and disassemble the end of mitosis, respectively. The SMC proteins, in addition to maintaining axis elasticity, are essential for the determination of the rod-like chromosome shape. The extreme compaction of mitotic chromosomes is determined mainly by the high amount of bivalent ions bound to DNA at mitosis.