Physical and data structure of 3D genome

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With the textbook view of chromatin folding based on the 30nm fiber being challenged, it has been proposed that interphase DNA has an irregular 10nm nucleosome polymer structure whose folding philosophy is unknown. Nevertheless, experimental advances suggested that such irregular packing is associated with many nontrivial physical properties that are puzzling from a polymer physics point of view. Here, we show that the reconciliation of these exotic properties necessitates modularizing 3D genome into tree data structures on top of, and in striking contrast to the linear topology of DNA double helix. Such functional modules need to be connected and isolated by an open backbone that results in porous and heterogeneous packing in a quasi-self-similar manner as revealed by our electron and optical imaging. Our multi-scale theoretical and experimental results suggest the existence of higher-order universal folding principles for a disordered chromatin fiber to avoid entanglement and fulfill its biological functions.