Fractal organization of chromatin in the nucleus of a biological cell

Project partners

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A brief description of the project proposal

Biological objects often have a fractal structure, which ensures their vital physiological functions. The most obvious implementation of this principle is a tree. It grows such that at each next level of branching, the sum of the squares of the radii of the branches is equal to the square of the radius of the branch from which the branching occurred. A recursive property describing the growth of a tree had already been noticed by Leonardo Da Vinci.

Biophysical mechanisms responsible for the fractal organization of the structure of living objects are quite complex and are a combination of many interacting factors, including random ones. This leads to the formation of not only "classical", fairly well-studied fractals, but also fractal structures with unusual e.g. logarithmic properties, a remarkable example of which is a tree. One more striking example is the concise packing of DNA strands in the cell nucleus. Despite the widespread and relative simplicity of organization, the properties of logarithmic fractals are poorly understood.

A deeper understanding requires the construction of an adequate mathematical model of a living fractal with a hierarchical structure and the physical interpretation of its parameters. In particular, such studies can help to resolve the question of how a meter-long DNA strand is packed into a micron core, and how the structure of this package provides rapid unpacking of specific sites for transcription or replication.

Here we propose an interdisciplinary study using a combination of complementary neutron scattering techniques (small-angle neutron scattering and quasi-elastic neutron scattering) to investigate experimentally the fractal structure and dynamics of DNA in the cell nucleus. The study aims to develop and validate a unified theoretical model of fractal organization of the living cell nucleus. The main role in solving this problem is played by computer modelling of neutron scattering processes on different fractal structures. The experimental and theoretical search for a clear connection between fractal structure and fractal processes in living organisms will pave the way for a better understanding of the basic principles of life.