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The Energy Landscape of Proteins

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Energy levels have been seminal concepts in physics for a long time, presumably starting with the Balmer series in hydrogen and continuing with the energy levels in more complex atoms, and in molecules, solids, nuclei, and particles. In complex systems, energy levels change to energy landscapes (EL), because they can assume a large number of different conformations. Understanding the energy landscape is important because transitions in the landscape correspond to fluctuations, relaxations, and reactions. For any complex system, the exploration of the EL is a formidable problem. Glasses and proteins are the systems where the energy landscapes are beginning to emerge from experimental, theoretical, and computational studies. Both systems are important; glasses for their many applications and proteins for their roles as building blocks of living matter. The energy landscape of even a simple protein is extremely complex. It is organized hierarchically into a number of tiers. Different tiers have characteristic properties and different functional roles. Two tiers stand out; fluctuations in these tiers are similar to the alpha and beta relaxations in glasses. In contrast to glasses, these fluctuations do not depend only on the protein, the environment (solvent) and the hydration shell of the protein, are crucially involved. Studies of these fluctuations, particularly using neutron scattering and the Mössbauer effect, promise to give more insight into protein functions and also into the physics of complex systems.