Abstract: We are used to describing systems of many particles by statistical mechanics. However, recently it was realized that the basic postulate of statistical mechanics -- ergodicity -- breaks down in so-called many-body localized systems, where disorder prevents particle transport and thermalization. In this talk, I will describe a recent theory of the many-body localized (MBL) phase, based on new insights from quantum entanglement. I will argue that, in contrast to ergodic systems, MBL eigenstates are not highly entangled, but rather obey so-called area law, typical of ground states in gapped systems. I will use this fact to show that MBL phase is characterized by an infinite number of emergent local conservation laws, in terms of which the Hamiltonian acquires a universal form. Turning to the experimental implications, I will show that MBL systems exhibit a universal response to quantum quenches: surprisingly, entanglement shows logarithmic in time growth, reminiscent of glasses, while local observables exhibit power-law approach to “equilibrium” values. I will close by discussing the transition between many-body localized and ergodic phases, as well as other recent developments in exploring ergodicity and its breaking in quantum many-body systems.

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