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QCD in Extreme Conditions

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Quantum Chromodynamics predicts that at some large temperature or density the strongly interacting matter transforms from the gas of observed hadrons into the plasma of quarks and gluons, ordinarily confined inside the hadrons. Since the inception of QCD the fundamental question of when and how this transformation is accomplished has been driving theoretical and then also experimental research. The phase diagram of QCD, the nature of the phases and the dynamics of QCD in the regime relevant to heavy ion collision experiments presents many challenges due to the nonperturbative character of QCD interactions. It is necessary to develop new theoretical ideas and tools to study these phenomena. I shall overview the past and present challenges, such as the nature and the location of the transition and of the critical point on the phase diagram, and how modern nuclear theory addresses them. I shall describe how recent experimental evidence points at a near-perfect fluidity of the matter created at RHIC, and how the theory meets the challenge of describing such a matter using time-tested techniques, such as numerical lattice calculations, as well as new analytical methods emerging from string theory.