While there are four commonly observed states of matter (solid crystal, liquid, gas, and plasma), we have known for some time now that there exist many other forms of matter. For example, both quasicrystals and liquid crystals are states of matter that possess properties that are intermediate between those of crystals and conventional liquids. The focus of my talk will be disordered hyperuniform many-body systems [1], which can be regarded to be a new state of disordered matter in that they behave more like crystals or quasicrystals in the manner in which they suppress large-scale density fluctuations, and yet are also like liquids and glasses because they are statistically isotropic structures with no Bragg peaks. Thus, disordered hyperuniform systems can be regarded to possess a "hidden order" that is not apparent on short length scales while being structurally rotationally invariant. I will describe a variety of different examples of such disordered states of matter. I will demonstrate that there exist classical ground states that are hyperuniform and disordered over a wide range of densities up to some critical density, below which the system undergoes a phase transition to ordered states [2]. Disordered hyperuniform systems appear to be endowed with novel physical properties, including complete photonic band gaps comparable in size to those in photonic crystals [3] and improved electronic band-gap properties. Moreover, we have recently shown that photoreceptor cell patterns (responsible for detecting light) in avian retina have evolved to be disordered and hyperuniform.

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