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The XYZ Affair: Tales of the Third (and Fourth) Hadrons[1]

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In the past 16 years, dozens of new fundamental particles have been discovered that are clearly hadrons (compounds of quarks interacting via the strong nuclear force, QCD), but do not seem to fit into either of the known hadron categories of meson (quark-antiquark) or baryon (3 quarks). Many of these "exotic" particles, called X, Y, and Z, are now believed to be tetraquarks, and in July, 2015 the LHC announced the discovery of pentaquark states, P_c. We begin by examining the basics of QCD, and then turn to the question of how conventional hadrons are identified, which allows one to distinguish exotics. After reviewing their experimental discovery, we consider the question of how exotics are assembled. Several competing physical pictures attempt to describe the structure of exotics: as molecules of known hadrons, as the result of kinematical effects, and others. I propose that they can arise due to the formation of compact diquarks, a well-known but under-appreciated phenomenon of QCD. The competing facts of kinematics and diquark confinement create an entirely new kind of bound state: not a molecule with well-defined orbits, but an extended object that lasts only as long as it takes for quantum mechanics to allow the separated quarks and antiquarks to "find" one another, and allow decays to occur. I discuss several observed effects that support this picture.

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