1 The Millenium Prize Problems

Visit http://www.claymath.org/Millennium_Prize_Problems/ to learn about the Millenium competition. For solving some of the great unsolved problems of Mathematics, the Clay Institute will award you $1,000,000. Among these is a problem in Yang-Mills theory:

http://www.claymath.org/Millennium_Prize_Problems/Yang-Mills_Theory/

If you read the description, you will find it stated rather abstractly. It is related to the problem of “confinement of quarks.”

We talked a bit about the strong interactions; how they involve quarks, interacting through gluons. But many of you pressed me on the question, “where are the quarks.” This question was asked almost immediately once the quark model was proposed. Particles with fractional charge should be easy to see. After all, one measures the charge on a single electron. But extensive searches showed no quarks.

With the development of QCD (quantum chromodynamics), the theory of quarks interacting with gluons (a type of Yang-Mills theory, see the announcement), the question became sharper. This theory readily explains the SLAC experiments which showed that protons and neutrons really do consist of quarks; many subsequent experiments have provided further verification. But it has a hard time explaining the hadrons. Solving the Schrodinger equation for this theory should give the proton mass and wave function, but this problem turns out to be very hard.

It is believed, however, that this theory exhibits the property of “confinement.” It is simply not possible to separate quarks. For a long time, this idea was viewed with skepticism, but there is by now a great deal of evidence from computer studies that this is the case. Basically, what these studies show is that if you try to pull off a quark from a hadron, instead of separating the quark, you produce quark-antiquark pairs, which bind together to form more hadrons. You never get a quark by itself.

While the numerical evidence is reasonably convincing, most particle physicists are still uneasy about this idea; it sounds like some sort of excuse; perhaps QCD is just wrong. I think this is why the large prize for providing an analytic explanation. The Clay announcement in terms of a “mass gap.” If any of you have any ideas how to prove confinement, come by; I’ll explain the equivalence of “mass gap” and “confinement”, and I’ll settle for just 1/3 of the award.