POP QUESTION TIME

THE QUESTION

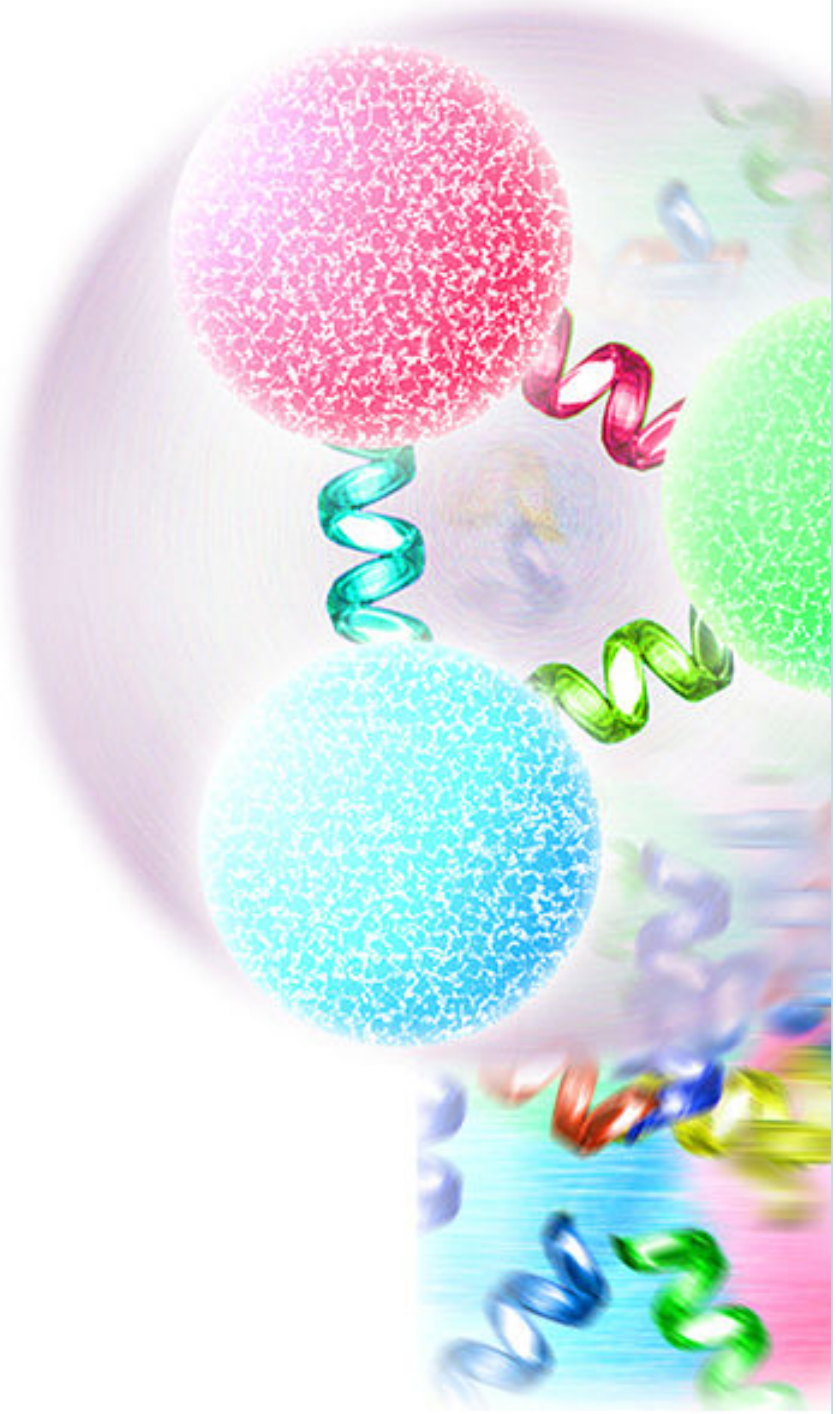
Protons are made of three quarks, it is said.
But the quark mass is much smaller than the proton mass.
How is this possible?

Forte's ANSWER (Part 1)

Actually, in a proton there are not just three quarks. In fact, in a proton there is an infinite number of quarks. Three is the total charge of the quarks: except that it is not the electric charge but rather the 'baryon number'. One way of thinking it is that in the proton there are three quarks with 'charge' (baryon number) 1/3, plus an infinite number of pairs made of a quark (baryon number 1/3) and an antiquark (baryon number -1/3).

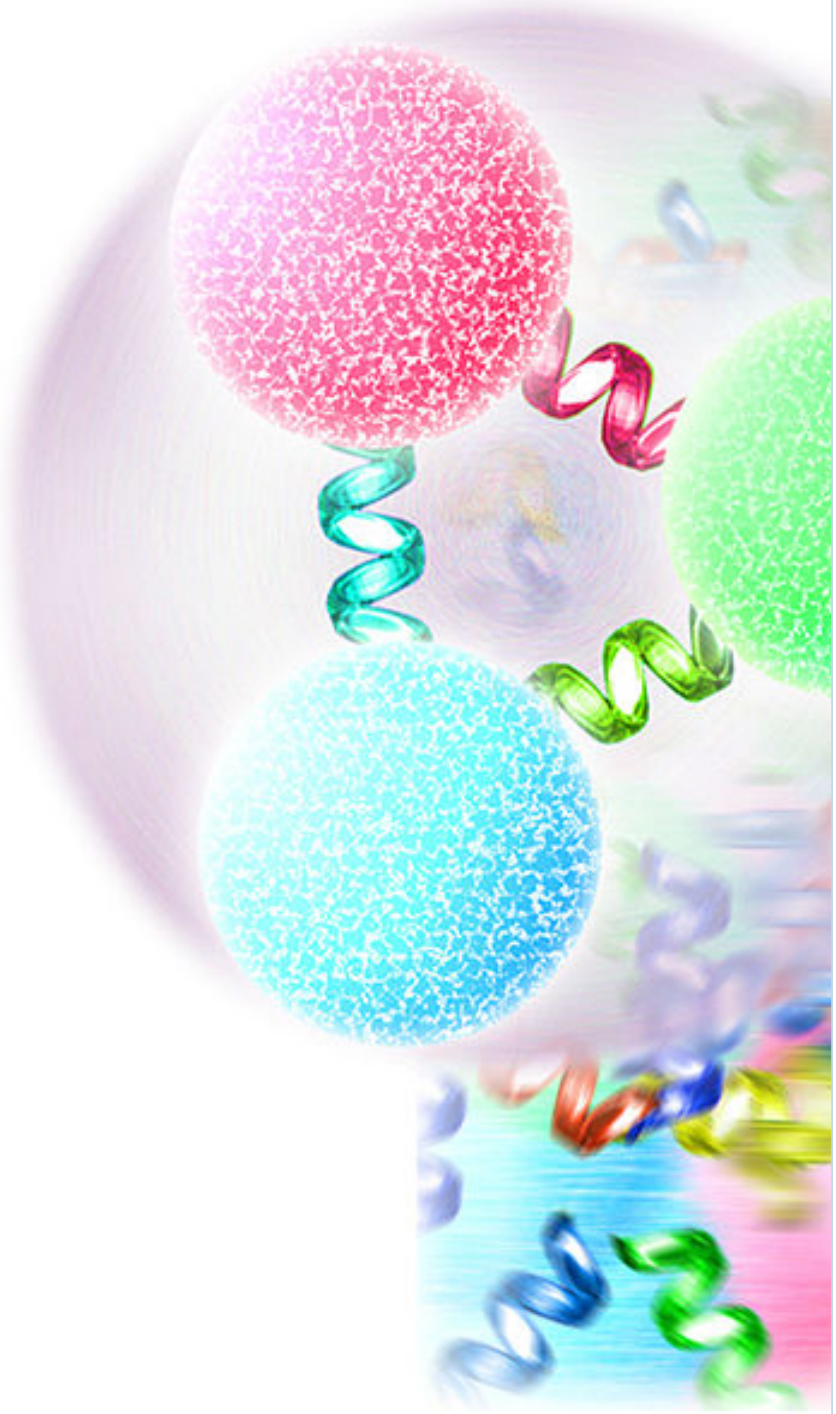
Forte's ANSWER (Part 2)

The mass of the proton is shared among these constituents: roughly, there is an infinite number of constituents that carry smaller and smaller fractions of the mass, so the total is finite even if the number of constituents is infinite.



Forte's ANSWER (Part 3)

If we add up the mass of all these quarks we find about half the mass of the proton. The other half is carried by the 'gluons': the 'glue' that binds the quarks with each other. Gluons are to the strong interactions what photons (i.e. light, made of electric and magnetic fields) are to electromagnetism. The electron is bound to the nucleus in an atom by the electromagnetic force, mediated by photon exchange; quarks are bound in one proton by the strong force, mediated by gluon exchange .



Forte's ANSWER (Part 4)

Both gluons and quarks have zero mass: gluons exactly zero, and the quarks that carry the proton baryon number very very small, two or three hundred times smaller than the proton mass. But even zero mass constituents, when tightly bound together, may build up a massive object. The mass of the bound state comes from the binding energy that holds the system together.