

THE ATOMIC MATRIOSHKA PROBLEM

So, nat'ralists observe, a flea
Hath smaller fleas that on him prey,
And these have smaller still to bite 'em
And so proceed *ad infinitum*.

Jonathan Swift (1733)

Human beings are obsessed with building blocks, forever pulling
them apart and putting them back together again.

Edward Wilson (1998)

With the quark model in hand, the entire subatomic zoo suddenly
started to make sense.

Robert Oerter (2006)

In Democritian atomism ... atoms are individual and indestructible
packets of being with an unchanging shape and size. They, along
with void, are the sole constituents of the universe.

Alan Chalmers (2009)

Yesterday was clueless but today I'm working on a Problem that my fictional detective would soon turn into a clue. What will Real Frank make of it? He's on the job today. Is he here because she too is in the office? She sports a shade of tan. Did she travel without telling? Her credit-card account will let me know. She offers nothing but the usual pleasantries. A few minutes at her desk and off she goes.

Gifts of *Matrioshka*, nested wooden dolls, most often seven of them, are traditional in Russia. True, they're kind of recent; but they do have antecedents. A little checking tells me that *Juni tamago*—up to twelve concentric egg-shaped figures—date back to maybe 1800 in Japan. When first one gets the gift, one doesn't know how many dolls will be revealed until the last comes into view. I thought to buy a set to show him; didn't find them so I pick a picture on the Web instead.

Thus also—I say with a verbal flourish that might make sense if I had the dolls in hand—with the atom. To almost any level one might want to do it, matter can be cut in pieces, and those pieces into pieces. Around 400 BCE the Greeks come up with the idea (though maybe Jains in India were sooner) that

when cutting matter into pieces there must be an end. That is, matter's made of little pieces that cannot be cut.

History assigns Democritus the credit. But for many centuries it's only an idea. He can't dismantle matter into atoms so he can't show they are real. He just imagines them and so invents a word: To the Greeks *atomos* means uncuttable. This isn't just a property, it is the essence of this Democritian idea.

It is a bright idea, and time will show that it is partly right. It takes two thousand years to figure atoms out. It comes together around 1800. Dalton gets the credit but he doesn't cut the matter into atoms. He shows that elements react *as if* they're made of atoms. Now science understands, or so it seems, the basic building blocks of matter. This understanding lasts a hundred years.

It takes that long for physicists to cut the atom into two: a nucleus and an electron cloud. Some think of it like a solar system. Its sun is the nucleus. It's very small. And the electron seems to have no size at all. The nucleus and cloud bear plus and minus charges. The rest of the seeming-solid atom is just empty.

Thus, in physics as in statecraft, divide-and-rule becomes the order of the day. Cutters cut uncuttable nuclei of uncuttable atoms into many pieces. They call them nucleons: protons, which are positive, and neutrons, which appear to bear no charge. Surely this must be the lowest level. But some wonder: Are these nucleons the long-sought basic building blocks or can they too be cut?

And sure enough this proves to be just one more round of find-the-*a-tom* frenzy. By the 1970s it's clear the proton and the neutron are both composite. They are proposed, then shown, to be composed of quarks.

The Standard Model's based on quarks. They come in six kinds. For fun physics gives them cutesy names: Up, down, charm, strange, top and bottom quarks. Up, charm and top quarks have a charge that is two-thirds of the electron's; down, strange and bottom quarks have half of that. They stick together—always—in twos or threes. For example, a proton is two up quarks and one down quark. A neutron is two downs and an up.

Three rounds to the cutters. If atoms are street level, quarks are in the sub-sub-basement. Will we see round four? Well, the Standard Model lines up the known particles (and a few yet to be found) in an elegantly ordered grouping. Surely this must show the lowest level. Quarks must be *the* smallest pieces. They—not what *we* call atoms—are the atoms Democritus had in mind. And so for several years it seems to be. But this too is an illusion.

The illusion gets some help from quarks themselves. It proves to be impossible to isolate one. It's not just that it takes a lot of energy to smash a nucleon. It can be done. But hit a quark with enough energy to jerk it out of, say,

a proton, and instead of setting the quark free, that energy just turns into another quark. The old and new quarks glue together. Isolate a quark and it will manufacture company.

But this can't keep them from the cutters. The ink is barely drying on the Standard Muddle when the cutting starts on quarks. Pati and Salam propose that all the quarks are made up of more-fundamental fundamental particles. They call them preons. And soon after, having kicked the preon football, Salam warns that Lucy can't be trusted. As he puts it: 'A contrasting point of view states ... that quarks and leptons are composed of pre-quarks (preons), preons are possibly composites of pre-preons, pre-preons of pre-pre-preons.' So Salam sees this much as Swift does with his fleas on fleas on fleas.

Are preons real? And if they're real, could they be uncuttable? If not, how many Matrioshka levels might be found beneath them? Will there ever be a final cut? It's strange that we still have no answer to this ancient question. But should this bother my detective?

Well, an afternoon of study finds that matter has its structure may be tied up with the structure of the universe. It's the universe's rules that make the matter have a structure. So how matter can be cut and, maybe even more so, how it *cannot* (if it can't) may be a clue to how the universe began.