

Edge question 2012

WHAT IS YOUR FAVORITE DEEP, ELEGANT, OR BEAUTIFUL EXPLANATION?

The Next Level of Fundamental Matter?

Haim Harari

A scientific idea may be elegant. It may also be correct. If you must choose, choose correct. But it is always better to have both.

“Elegant” is in the eye of the beholder. “Correct” is decided by the ultimate judge of science: Mother Nature, speaking through the results of experiments. Unlike the standard TV talent contests, neither “Elegant” nor “Correct” can be determined by a vote of the public or by a panel of sneering judges. But the feeling that an idea is elegant often depends on the question that is being asked.

All of matter consists of six types of quarks and six types of leptons, with seemingly random unexplained mass values, spanning more than ten orders of magnitude. No one knows why, within these twelve building blocks, the same pattern repeats itself three times. Some of these objects may also convert into each other, under certain circumstances, by unexplained rates, called “mixing angles”. The twenty odd values of these rates and masses seem to be arbitrarily chosen by someone (Nature or God). This is what the standard model of particle physics tells us. Is this elegant? It does not seem so.

But the fact that mountains and snakes, oceans and garbage, people and computers, hamburgers and stars, diamonds and elephants, and everything else in the universe, are all made of only a dozen types of fundamental objects, is truly mind boggling. That is exactly what that same standard model says. So is it elegant? Very much so.

My great hope, for the last 32 years (a neat 100,000 years in binary notation), has been that Nature is actually even more elegant. The twelve fundamental quarks and leptons, and their anti-particles, all have electric charges 0, $1/3$, $2/3$ and 1, or the negative values of the same numbers. Each value repeats exactly three times.

There is no satisfactory explanation for many questions: Why all charges are multiples of $1/3$ of the electron charge? Why each value between 0 and 1 appears on the list, and does so with the same number of times? Why they never acquire more than three doses of that

quantity? Why the same entire pattern repeats itself three times? Why the leptons always have integer charges and the quarks always non-integers? Why quark charges and lepton charges are at all related to each other by simple ratios?

The fact that mosquitoes, chairs and tomato juice, are all electrically neutral, results from the unexplained equality of the magnitudes of the electric charges of protons and electrons, causing atoms to be neutral. This follows from the quarks charges having precise simple ratios to the lepton charges. But why is the electron not having a charge of, say, 0.8342 of that of the proton? Why do they have exactly the same charge value?

A very elegant explanation for all of these puzzles would appear, if all quarks and leptons, and therefore all matter in the universe, would consist of only two building blocks, one with electric charge of $1/3$ of the electron charge and one without electric charge. Then all combinations of such three objects might exactly create the known pattern of quarks and leptons, and would neatly answer the above questions. The bizarre list of masses and conversion rates of the quarks and leptons would still remain unexplained, but would be relegated to a level of discussion of understanding the dynamical forces, binding the two more fundamental basic objects into a variety of compounds, rather than as God-given or Nature-given long list of more than twenty free fundamental parameters.

An Elegant explanation? Certainly. Correct? Not necessarily, as far as we know now. But you can never prove that particles are not made of more fundamental objects. This may always be discovered in the future, without contradicting any currently known data, especially if the new structure is revealed only at smaller distances and higher energies than anything we have seen so far, or if it obeys a strange new set of basic physics rules. Needless to say, such a simple hypothesis needs to tackle many additional issues, some of which it does beautifully, while in others it fails badly. That may be the partly justified reason for the general negative attitude of most particle physicists to this simple explanation.

I find the idea of creating the entire universe from just two types of basic building blocks (which I call "Rishons" or primaries), a very elegant and enticing explanation of many observed facts. The book of Genesis starts with a universe that is "formless and void" or, in the original Hebrew "Tohu Vavohu". What better notations for the two fundamental objects than T (Tohu, formless) and V (Vohu, void), and then each quark or lepton consists of a different combination of three such Rishons (like TTV or TTT). This may remain forever as a very elegant, but incorrect, idea, or may be revealed one day as the next level of the structure of matter, following the atom, the nucleus, the proton and the quark. Ask Mother Nature. She understands both "Elegant" and "Correct", but she is not yet telling.