THE PROBLEM OF SMALL NUMBERS

One of the mysterious aspects of the mass problem is the absurdly tiny size that the values that the masses of ordinary particles have when measured in absolute units. For example, the mass m_e of the electron, in absolute units, is about

m_e = 0.000,000,000,000,000,000,000,043....

Roger Penrose (2004)

It is becoming clearer and clearer that the hardest problem faced by theoretical physics is the problem of accounting for the small value of the cosmological constant.

Lee Smolin (2005)

Why are the constants of nature such awkward numbers? Why can't they be simple numbers, such as 2 or 5 or even 1? Why are they always so small (Planck's constant, electron charge) or so large (Avagadro's number, speed of light)?

Leonard Susskind (2008)

While the coffee monster burps, my question is: How do I explain that physics is beset by numbers that appear to be too small? It's going to be difficult to get across because he has no gut-feel for this stuff. He won't know that there *is* gut-feel for physics. It's a close-kept secret. 'Gut feeling for physics' gets one hit on Google—a rarity, a concept that's next to anonymous. Bing too says just one; it must be true. Nonetheless a little study shows there *are* gut feelings about physics. One is: Some numbers in the universe feel far too small. Another thing I'm not sure that I can explain is: How do tiny numbers turn into a clue? And there is a new twist to my daily puzzle: Who do I explain to? Or to whom?

Of course a number can be anything; its size cannot be *wrong*. It's more like finding something out of place—like a flea found floating alongside a galaxy. Something of this kind is what one needs to have in mind in trying to take in what Penrose finds 'absurdly tiny' in the mass of the electron. And Barrow is exclaiming at the biggest of the little-number problems. It's a number so near zero that he has it in his *Book of Nothing*. It's that so-called vacuum energy—the bit of it that can't be taken out of so-called empty space. Its measured value is way smaller than it should be, say the physicists. They would be happier if it were zero. That would be simpler to explain. But instead it is fantastically tiny. And it's not the only number feel-for-physics finds too small.

The best—as in most basic—numbers bear the name of Planck. Planck's constant $\hbar$ is QM's bedrock. It's thought by those who think such things to be a fundamental number. It gets a fuzzy start in life as, in despair, Planck tries to fathom the behavior of black-body radiation. Heisenberg soon tucks it into his Uncertainty Principle. It's *very* small. In the '20s and the '30s as quantum mechanics kick the tires and check the revs on their new QM sports car, they find Planck's $\hbar$ all over.

Twenty years before Planck's insight a philosopher, George Stoney, works on numbers. He dislikes arbitrary units, like the length of someone's foot that holds sway to this day. He thinks there could be, should be, must be, units that are natural. He proposes basic units for time, mass and size. They all turn out to be tiny. Then Planck proposes similar ideas, basing them on his new constant. Soon there's a Planck time, like—but better known than—Stoney's. Compared to times that can be measured it is *very* small. And there's the *Planck size*. Penrose says, 'This distance is considered to be of profound relevance in quantum gravity theory.' A hydrogen atom has about a billionth of the width of a baseball. Small. The proton at its center is about a hundred thousand times smaller again. Incredibly small. The Planck size is some 100,000,000,000,000,000,000 times smaller than the proton. Why is this distance so ridiculously small compared to things that people think of as ridiculously small? It's like physics has a ruler that's too small to take to school. My gut-feel says the Problem of Small Numbers is: So if the standard ruler is much smaller than an atom, *what* is going on down there at sizes where it's useful?

What are these numbers anyway? Where do they come from? And, since it seems to me the answer to this latter question has to be from the Beginning, the puzzle of their tiny size may be a clue.