16 Why is the Quantum World so Small?

- The energy of a photon of visible light is approximately 0.000000000000000001 Joules.
- The (negative) charge of an electron is 0.0000000000000000016 Coulombs.
- The time that an atom remains in an excited state before making a transition to a lower state is approximately 0.000000001 seconds.
- The average energy of a hydrogen molecule in a gas at 0⁰ C is approximately 0.000000000000000001 Joules.
- The average distance of an electron from the nucleus in a hydrogen atom is 0.000000000053 meters.

Why are these numbers so small? The answer is that they are not necessarily small. We are big. The overwhelming majority of the estimated 8.7 million species on Earth are too small to be seen with the naked eye - and only a small number of animal species are bigger than we are.

The numbers quoted above which are typical numbers encountered in the quantum world are "small" because they are quoted in units which humans have defined to be of the size relevant to our everyday experiences in the macroscopic world:

- A joule is approximately the energy used in lifting a small object off the floor.
- A second is approximately the time taken to say "one alligator".
- A meter is a little over half the height of an average human.
- A kilogram is the mass of an object that we can comfortably throw.
- A coulomb is approximately the charge that passes through a small torch bulb in three seconds.

So the question should really be "Why are we so big?". One of the consequences of our size is that we have big brains. Our nervous system has 86 billion neurons, whereas a mouse only has 71 million neurons. These large brains make us sufficiently intelligent to be able to study physics, biology and other disciplines in order to discover (at least some of) the secrets of Nature. In particular, this enables us to pose the question above. Therefore according to the reasoning of the **"anthropic principle"**, we must be the size we are, so that our brains are sufficiently developed to enable us to pose the question in the first place. Many scientists find this anthropic principle "distasteful" because it invokes the concept of human consciousness to answer a question about Nature, which is assumed to be objective. Nevertheless the logic of this method of reasoning is well-founded. There are many species that are much smaller than we, and some of the single-cell bacteria have dimensions which are only a little larger than those of typical quantum phenomena. However, these microscopic species do not ask questions about their size in comparison with quantum scales.