The Recipe for Our Universe
(Taken from Martin Rees, *Just Six Numbers*)

N = a value measuring the strength of the electrical forces that hold atoms together, divided by the force of gravity between them. N is a large number: 1,000,000,000,000,000,000,000,000,000, 000, 000, 000. If you are counting, that's 1 followed by 36 zeros. If N had a few less zeros, only a short-lived miniature universe would exist. No creature could grow larger than an insect, and there would be no time for biological evolution.

e **=** a value defining how firmly atomic nuclei bind together and how all the atoms one earth were made. This value controls the power of the sun and how stars transmute hydrogen into all the atoms on the periodic table. So, for instance, carbon and oxygen are common, whereas gold and uranium are rare because of the value of this number. The value of this number is 0.007. If it had been 0.006 or 0.008, we could not exist.

W (omega) = the amount of material in the universe (galaxies, diffuse gas, and dark matter). This value concerns the importance of gravity and expansion energy in the universe. It determines the expansion rate of the cosmos and the eventual fate of the cosmos. If the average mass-density of the Universe exceeds about five atoms per cubic meter, then the Universe has a density high enough to eventually halt its expansion (gravity will overcome expansion energy) and the Universe will collapse. Otherwise expansion energy will have the upper hand and U the universe will expand for eternity. *Critical density* refers to the mass-density that places the Universe on the border of eventual collapse and eternal expansion (and gives it a flat or Euclidean geometry). Omega is the ratio between the actual and critical density. Full critical density is an Omega = 1. The average density today is at least 0.3. But if omega is now at least 0.3, it must not have been too far off from 1 a second or two after the big bang. Deviations from unity or 1 would have been amplified during expansion. Thus if omega began much higher than 1, gravity would have quickly overcome expansion energy. If omega were much less than 1, expansion energy would have overcome gravity, which would have thrust omega toward zero. For instance, a beginning omega of .5 would have dropped to .25 after the universe expanded to a factor of two. So because omega is at least 0.3 today, it could not have been too far from 1 immediately after the big bang. The Universe likely has a flat geometry, but this flatness is an indication of an importance balance between expansion and gravity.

l (Lambda) = a anti-gravity force that controls the expansion of the universe at scales beyond 1 billion light years. It will eventually become more dominant than gravity and other forces as the universe becomes emptier with time. l must be very small, though this is unusual. If it had been slightly larger it would have effected the universe at scales less than a billion light-years and thus would have stopped galaxies and stars from forming. Cosmic evolution would never have started.

Q = a value that determines the fabric or large scale features of the universe – stars, galaxies, and galaxy clusters. It represents the ration of two fundamental energies and is roughly 1/100,000. If Q were smaller, the universe would be inert and without structure. If Q were much larger, the universe would be a violent place, in which neither stars or solar systems could exist. At the time of the big bang, the universe had just the right about roughness imposed on the right amount of smoothness to give us a universe with the sort of cosmic evolution that entails the sort of spatial order we observe.

D = the value representing the spatial dimensions to the universe. D = 3. Life could not exist if D = 2 or 4. Time is a forth dimension. Whereas time has an intrinsic arrow or directionality that moves us "forward," D does not.

The emergence and existence of life in the cosmos is highly sensitive to these numbers in a variety of ways. Consider, for instance: life => stable and complex chemical compounds => carbon => stable and massive stars => hydrogen atoms.