**Fine Tuning Parameters for the Universe**

1. strong nuclear force constant
   *if larger*: no hydrogen would form; atomic nuclei for most life-essential elements would be unstable; thus, no life chemistry
   *if smaller*: no elements heavier than hydrogen would form: again, no life chemistry
2. weak nuclear force constant
   *if larger*: too much hydrogen would convert to helium in big bang; hence, stars would convert too much matter into heavy elements making life chemistry impossible
   *if smaller*: too little helium would be produced from big bang; hence, stars would convert too little matter into heavy elements making life chemistry impossible
3. gravitational force constant
   *if larger*: stars would be too hot and would burn too rapidly and too unevenly for life chemistry
   *if smaller*: stars would be too cool to ignite nuclear fusion; thus, many of the elements needed for life chemistry would never form
4. electromagnetic force constant
   *if greater*: chemical bonding would be disrupted; elements more massive than boron would be unstable to fission
   *if lesser*: chemical bonding would be insufficient for life chemistry
5. ratio of electromagnetic force constant to gravitational force constant
   *if larger*: all stars would be at least 40% more massive than the sun; hence, stellar burning would be too brief and too uneven for life support
   *if smaller*: all stars would be at least 20% less massive

than the sun, thus incapable of producing heavy elements

6. ratio of electron to proton mass
   *if larger*: chemical bonding would be insufficient for life chemistry
   *if smaller*: same as above
7. ratio of number of protons to number of electrons
   *if larger*: electromagnetism would dominate gravity, preventing galaxy, star, and planet formation
   *if smaller*: same as above
8. expansion rate of the universe
   *if larger*: no galaxies would form
   *if smaller*: universe would collapse, even before stars formed
9. entropy level of the universe
   *if larger*: stars would not form within proto-galaxies
   *if smaller*: no proto-galaxies would form
10. mass density of the universe
    *if larger*: overabundance of deuterium from big bang would cause stars to burn rapidly, too rapidly for life to form
    *if smaller*: insufficient helium from big bang would result in a shortage of heavy elements
11. velocity of light
    *if faster*: stars would be too luminous for life support *if slower*: stars would be insufficiently luminous for life support
12. age of the universe
    *if older*: no solar-type stars in a stable burning phase would exist in the right (for life) part of the galaxy
    *if younger*: solar-type stars in a stable burning phase would not yet have formed

13. initial uniformity of radiation

*if more uniform*: stars, star clusters, and galaxies would not have formed

*if less uniform*: universe by now would be mostly black holes and empty space

14. average distance between galaxies

*if larger*: star formation late enough in the history of the universe would be hampered by lack of material

*if smaller*: gravitational tug-of-wars would destabilize the sun's orbit

15. density of galaxy cluster

*if denser*: galaxy collisions and mergers would disrupt the sun's orbit

*if less dense*: star formation late enough in the history of the universe would be hampered by lack of material

16. average distance between stars

*if larger*: heavy element density would be too sparse for rocky planets to form

*if smaller*: planetary orbits would be too unstable for life

17. fine structure constant (describing the fine-structure splitting of spectral lines) *if larger*: all stars would be at least 30% less massive than the sun

*if larger* than 0.06: matter would be unstable in large magnetic fields

*if smaller*: all stars would be at least 80% more massive than the sun

18. decay rate of protons

*if greater*: life would be exterminated by the release of radiation

*if smaller*: universe would contain insufficient matter for life

19. $^{12}C$ to $^{16}O$ nuclear energy level ratio

*if larger*: universe would contain insufficient oxygen for

life
*if smaller*: universe would contain insufficient carbon for life

20. ground state energy level for $^4He$
*if larger*: universe would contain insufficient carbon and oxygen for life
*if smaller*: same as above

21. decay rate of $^8Be$
*if slower*: heavy element fusion would generate catastrophic explosions in all the stars
*if faster*: no element heavier than beryllium would form; thus, no life chemistry

22. ratio of neutron mass to proton mass
*if higher*: neutron decay would yield too few neutrons for the formation of many life-essential elements
*if lower*: neutron decay would produce so many neutrons as to collapse all stars into neutron stars or black holes

23. initial excess of nucleons over anti-nucleons
*if greater*: radiation would prohibit planet formation
*if lesser*: matter would be insufficient for galaxy or star formation

24. polarity of the water molecule
*if greater*: heat of fusion and vaporization would be too high for life
*if smaller*: heat of fusion and vaporization would be too low for life; liquid water would not work as a solvent for life chemistry; ice would not float, and a runaway freeze-up would result

25. supernovae eruptions
*if too close, too frequent, or too late*: radiation would exterminate life on the planet
*if too distant, too infrequent, or too soon*: heavy elements would be too sparse for rocky planets to form

26. white dwarf binaries
*if too few*: insufficient fluorine would exist for life chemistry
*if too many*: planetary orbits would be too unstable for life
*if formed too soon*: insufficient fluorine production
*if formed too late*: fluorine would arrive too late for life chemistry
27. ratio of exotic matter mass to ordinary matter mass
*if larger*: universe would collapse before solar-type stars could form
*if smaller*: no galaxies would form
28. number of effective dimensions in the early universe
*if larger*: quantum mechanics, gravity, and relativity could not coexist; thus, life would be impossible
*if smaller*: same result
29. number of effective dimensions in the present universe
*if smaller*: electron, planet, and star orbits would become unstable
*if larger*: same result
30. mass of the neutrino
*if smaller*: galaxy clusters, galaxies, and stars would not form
*if larger*: galaxy clusters and galaxies would be too dense
31. big bang ripples
*if smaller*: galaxies would not form; universe would expand too rapidly
*if larger*: galaxies/galaxy clusters would be too dense for life; black holes would dominate; universe would collapse before life-site could form
32. size of the relativistic dilation factor
*if smaller*: certain life-essential chemical reactions will

not function properly
*if larger*: same result

33. uncertainty magnitude in the Heisenberg uncertainty principle
*if smaller*: oxygen transport to body cells would be too small and certain life-essential elements would be unstable
*if larger*: oxygen transport to body cells would be too great and certain life-essential elements would be unstable

34. cosmological constant
*if larger*: universe would expand too quickly to form solar-type stars

Taken from Big Bang Refined by Fire by Dr. Hugh Ross, 1998. Reasons To Believe, Pasadena, CA.