1.3 – The Fine-tuning of the Laws of Nature

"Even if we can show that something created the universe, how do we know that it created us on purpose? Couldn't we just be an accident? Is there any reason to believe that… the universe isn't just random? How do we know that we're not just a cosmic hiccup?" (*Reason Series*, DVD 3)

Recent research in cosmology has shown that the universe has to have a specific set of conditions in order for it to sustain life. So we can actually calculate how likely it is that a randomly designed universe would have these conditions necessary to support life. These conditions are so improbable that most physicists believe that they couldn't have happened by chance.

1) The very special initial conditions of the universe
2) Constants in the physical laws governing the universe are fine-tuned for the possibility of life.

I. The Initial Conditions of the Universe

The two laws of thermodynamics. These laws are about energy, order and disorder in systems.

1) Energy - The *first law* of thermodynamics: The energy in an isolated system is constant.

Ex. Imagine a rock is at the top of a hill. It has a lot of *potential energy* due to gravity. When the rock rolls *down* the hill, it gathers speed. So the *kinetic energy* of motion increases as the potential energy due to gravity decreases. Potential energy is converted into kinetic energy. Now, if the rock runs into something at the bottom of the hill, that kinetic energy is converted into *heat energy*. Whatever it runs into and even the air it moves through will increase a bit in temperature. Carpenters know this, because when they hammer a nail in a bunch of times, the nail heats up. Energy can change form but the total in a closed system remains constant.

2) Entropy - The *second law* of thermodynamics

- Entropy is a measure of the disorder in a system. Low entropy means a very organized state. High entropy means a disorganized state.

Ex. **Iced tea** - If you took hot tea and put it into a thermos with ice in it, what will happen? The hot tea will melts the ice and it will get cold. Some of the ice will melt and become cold water. Over time it will all mix together and you'll get cold tea. And it always happens this way. Could you put ice tea into a thermos and expect it to change into hot tea and ice cubes? No!

- In a closed system, over time things are going to mix together. The hot things will always cool down, and the cold things will warm up until everything is at combined temperature in the middle.The level of entropy always goes up and it doesn't go back down again. This is why most of the processes we see around us only go in one direction: from order to disorder.

3) The entropy of the entire universe

- The universe is a *closed system*, because there is no energy source outside the universe that can transfer energy into or out of it. Why? Because everything that affects the universe is *inside* the universe already. So the entropy of the entire universe is always increasing.
- That tells us something about the past, as well. "As you go into the past things get less and less random. So that means at the beginning of time, in other words, at the Big Bang, things were highly organized." (Sir Roger Penrose, http://www.youtube.com/watch?v=GvV2Xzh11r8))

5) How unlikely is this low entropy start to the universe?

"How special was it? You can actually work this out. It's so special that the odds against this special initial state coming about by chance are less than 1 part in 10 to the power of 10 to the power 123… This is fine tuning. This is incredible precision in the organization of the initial universe." (Sir Roger Penrose, The Big Bang's low entropy condition, http://www.youtube.com/watch?v=GvV2Xzh11r8)

- 10 to the 10^{th} to the 123 against our universe. If you wrote out every zero in 10 point font it would fill most of the Milky Way galaxy.

6) Low entropy is necessary for life to exist in the universe

- We needed a very low initial level of entropy in the universe to get suns and planets, and ultimately life. Suns and planets could not have formed if the universe began with high entropy, and life could not exist.

II. The Constants of the universe

A. Physical Laws of Nature

- The physical laws of nature rule how things work in the universe: the law of gravity, the laws of motion, laws of electromagnetism, and the laws of thermodynamics we mentioned earlier.
- A *constant* is a number in the mathematical equations for the laws of nature. It is the same everywhere in the universe and over time. A constant never changes.

Ex. The speed of light in a vacuum, the mass of a proton, the mass of electron, etc.

Ex. Consider the engine of a car, there are many possible ways that an engine could be made. It has various parameters that could be changed to make the engine run better (the size of the pistons, the fuel/air mixture, the timing of the spark firing, the idle speed, etc.). This requires careful engineering.

B. Fine tuning of the Constants

- The laws of nature could still work with different values for these constants (~20 independent ones). There is no scientific reason why they have the exact values that they have.
- Physicists have discovered that if any one of several of these constants were altered in even minor ways, life would not be possible. Here are some examples.

1) Gravitational constant

- "If the weak force constant or the gravitational constant were higher or lower by just one part in 10 to the 50^{th}, then either the universe would have kept exploding forever (and that's very bad for life forms) or it would have catastrophically collapsed (also not good for life)." (Reason Series, DVD 3)

2) Strong Nuclear Force Coupling Constant

- "If the Strong Nuclear Force Coupling Constant were just 2 percent higher, there would be no hydrogen in the universe, and that means no stars and no life. But if [it] were just 2 percent lower, there would be no elements heavier than hydrogen, and that means no carbon as the building block for life. So either way we're out of luck." (Reason Series, DVD 3)

3) Constants determine possible types of stars

- "Stars that can support life like the sun lie right between two extreme states that are hostile to life: blue giants and red dwarfs. If electromagnetism, the gravitational constant, or the mass of the proton relative to the mass of the electron vary from their values by a super small fraction either higher or lower, then all the stars in the universe would be either blue giants, emitting tremendous amounts of radiation and frying everything in sight, or red dwarfs emitting so little radiation that life would never have a chance. Once again, just a fractional difference would make life impossible." (Reason Series, DVD 3)

4) Carbon resonance energy

- Finely-tuned resonance energy of carbon was necessary for carbon-based life forms to exist.

> "A common sense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature. The numbers one calculates from the facts seem to me to be so overwhelming as to put this conclusion almost beyond question." (Sir Fred Hoyle, "The Universe: Past and Present Reflections," *Engineering and Science*, November, 1981. pp. 8–12)