Evolution in the Multiverse

Russell K. Standish
High Performance Computing Support Unit
University of New South Wales
Sydney, 2052
Australia
R.Standish@unsw.edu.au
http://parallel.hpc.unsw.edu.au

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Abstract

In the *Many Worlds Interpretation* of quantum mechanics, the range of possible worlds (or histories) provides variation, and the Anthropic Principle is a selective principle analogous to natural selection. When looked on in this way, the "process" by which the laws and constants of physics is determined not too different from the process that gave rise to our current biodiversity, i.e. Darwinian evolution. This has implications for the fields of SETI and Artificial Life, which are based on a philosophy of the inevitability of life.

1 Introduction

The *Many Worlds Interpretation* (MWI)[6] of Quantum Mechanics has become increasingly favoured in recent years over its rivals, with a recent straw poll of eminent physicists[18, pp170–1] showing more than 50% support it. David Deutsch[7] provides a convincing argument in favour of MWI, and the *multiverse* in the title is due to him. Tegmark[17] has somewhat waggishly suggested that a *Principle of Plenitude* (alternatively *All Universes Hypothesis* — AUH), coupled with the *Anthropic Principle*[1][2][3] (AP) could be the ultimate *theory of*

[1] http://www.anthropic-principle.com

[2] The *Anthropic Principle* is a statement that the universe we observe must be consistent with the existence of us as observers. In the all universes hypothesis, the anthropic principle acts to select those universes that are "interesting", i.e. capable of supporting self aware consciousness. In this all universes picture, the distinction between the weak and strong forms of the anthropic principle is meaningless, so we will simply refer to the Anthropic Principle throughout ths paper.

everything (TOE). Tegmark's Plenitude consists of all mathematically consistent logical systems, the principle of plenitude according each of these systems physical existence, however by the anthropic principle, we should only expect to find ourselves in a system capable of supporting *self-aware substructures*, i.e. conciousness. Alternative Plenitudes have been suggested, for example Schmidhuber's[14] all possible programs for a universal turing machine. I have argued elsewhere[16], that the quantum mechanical subset of the Plenitude, namely the Multiverse, is the most likely system to be observed by conscious beings.

In this paper, we accept the MWI or Multiverse as a working hypothesis, and consider what the implications are for evolutionary systems. An evolutionary system consists of a means of producing variation, and a means of selecting amongst those variations (natural selection). Now variations are produced by chance and in the Multiverse picture, this corresponds to a branching of histories, whereby a particular entity's offspring will have different forms in different histories. The measure of each variant is related to the proportions in which the variants are formed, and the measure of each variant evolves in time through a strictly deterministic application of Schrödinger's equation.

What, then, determines which organisms we see today, given that a priori, any possible history, and hence any mix of organisms may correspond to our own? Is natural selection completely meaningless?

The first principle we need to apply is the anthropic principle, i.e. only those histories leading to complex, self-aware substructures will be selected. We also need to apply the *self sampling assumption*[4, 5] (SSA). The SSA is that each observer should regard itself as a random sample drawn from the set of all observer. It is the implicit assumption used in Carter and Leslie's Doomsday argument[9], and much other anthropic reasoning. Stated another way, as observers, we should expect to see a world that is nearly maximal in measure, subject to it being consistent with our existence. In this picture, natural selection is a process that differentiates the measure attributed to each variant organism.

2 Complexity Growth in Evolution

As I argued elsewhere[16], lawful universes with simple initial states by far dominate the set consistent with the AP. So the AP fixes the end point of our evolutionary history (existence of complex, self-aware organisms), and the SSA fixes the beginning (evolutionary history is most likely started with the simplest organisms). We should therefore expect to see an increase in complexity through time.

What about living systems not governed by the anthropic principle? Examples include extra terrestrial life (within our own universe, if it exists) and artificial life systems. Nonhuman terrestrial life is governed by the AP, since one expects that the evolutionary process that produced us will also produce the numerous other organisms found on Earth. A system of life that has evolved completely independently of Earth has no requirement to produce intelligent beings, and unless complexity growth is inevitable given the laws of physics and chemistry, no requirement to produce complex life forms. Proponents of SETI (the *Search for Extra-Terrestrial Intelligence*) believe in an inevitability of the evolution of intelligent life, given the laws of physics. The anthropic principle does indeed ensure that the laws of physics are compatible with the evolution of intelligence, but does not mandate that this should be likely (excepting, obviously in our own case). Hanson[8] has studied a model of evolution based on easy and hard steps to make predictions about what the distribution of such steps should be within the fossil record. He finds that the fossil record is consistent with there being 4–5 hard steps in getting to intelligent life on Earth. By hard steps, he means steps who's expected duration greatly exeeds the present age of the universe. The hard steps include

- origin of first replicator
- origin of sex
- origin of eukaryotic cells
- origin of multicellularity
- possibly the origin of self-aware conscious entities

This would imply that intelligent life is fairly unique within our own universe, to the chagrin of the SETI proponents, but simple prokaryotic life may well be ubiquitous. Of course, it is also true that a single example of extra terrestrial intelligence would be an important counterexample to these arguments based on the AP and SSA, so SETI is by itself not a fruitless exercise.

Likewise, for artificial life, it would seem plausible that a serious of easy and hard steps are required to climb the complexity ladder. Already, the first such hard transition (the creation of replicators from the primeval soup) has been observed[11, 10], but equivalents of other transitions (eg transition to sexual reproduction, prokaryote to eukaryote or multicellularity) have not been observed to date. Ray is leading a major experiment designed to probe the transition to multicellularity[12, 13] — success in this experiment will provide remarkable constraints on just how finely tuned the physics and chemistry needs to be in order for the system to pass through a hard transistion.

Adami[1, 2] and co-workers examined the *Avida* alife system for evidence of complexity growth during evolution. They did find this, although this is largely seen as the artificial organisms learning how to solve arithmetic problems that have been imposed artificially on the system. An analogous study by myself[15] of Tierra showed no such increase in complexity over time — if anything the trend was to greater simplicity. This work is still in progress.

3 Evolutionary Physics?

Returning back to the picture of the "All Universes Hypothesis", we can see that our current universe is made up from contingency and necessity. The necessity comes from the requirements of the anthropic principle, however when a particular aspect of the universe is not constrained by the AP, its value must be decided by chance (according to the SSA) the first time it is "measured" by self-aware beings (this measurement may well be indirect — properties of the microscopic or cosmic worlds will need to be consistent with our everyday observations at the macroscopic level, so may well be determined prior to the first direct measurements). Evolution is also described as a mixture of contingency and necessity. When understood in terms of the AP supplying the necessary, and the SSA supplying the rationale for resolving chance, the connection between the selection of phyical laws and the selection of organisms in evolution is made clear. It is as though the laws of physics and chemistry have themselves evolved. Perhaps applying evolutionary principles to the underlying physico-chemical laws of an alife system will result in an alife system that can pass through these hard transitions.

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