A Critique of Cosmological Natural Selection

Gordon McCabe

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Abstract

Mathematical physicist Lee Smolin has proposed a theory of Cosmological natural selection which, he argues, explains the existence of our life-supporting universe, and which, he claims, is superior to Anthropic Principle explanations. I will argue in this paper that the theory of Cosmological natural selection does not provide an improvement upon the Weak Anthropic Principle.[1]

According to current mathematical physics, there are many aspects of our physical world which are contingent rather than necessary. These include such things as the values of the constants in elementary particle physics, the values of the co-efficients in the laws of physics, and the initial conditions in General Relativistic models of the Universe. These can be referred to collectively as the parameters of physics. Study has revealed that the existence of life is very sensitively dependent upon the values of these parameters. If a universe had values for these parameters only slightly different from the values they possess in our own universe, then that universe would be incapable of supporting life. Hence, people have sought to explain why a life-supporting universe exists.

The Weak Anthropic Principle (WAP) provides one such explanation. The WAP hypothesizes the existence of a collection of universes, with different universes in the collection having different values for the parameters of physics. The WAP suggests that some of these universes have the combination of parameter values which permit life, and in at least one such universe, life and intelligent life exists. Amongst all the possible contingent values for the parameters of physics, intelligent life can only observe those values consistent with its own existence, (see Barrow and Tipler, [1]).

Opposing the Weak Anthropic Principle is Lee Smolin's theory of Cosmological natural selection. Smolin argues that the introduction of natural selection into cosmology can explain the existence of our life-supporting universe. He claims that to argue in the manner of the anthropic principle, "is not to reason, it is simply to give up looking for a rational explanation," (Smolin, [2], p39).

To expound Smolin's idea, it is first necessary to appreciate that natural selection can be precisely defined mathematically, in complete abstraction from

[1]This work was completed with the kind assistance of John Preston and David Oderberg from the University of Reading, Department of Philosophy.

any particular physical instance. Natural selection can be precisely defined by a set of conditions, tantamount to mathematical axioms. If a collection of objects satisfies these conditions, then that collection will evolve by natural selection, irrespective of what those objects are. Biological evolution by natural selection, discovered by Darwin, is just one particular case.

John D. Barrow asserts that natural selection (or, as he calls it, 'Darwinian evolution'), "has just three requirements:

- The existence of variations among the members of a population. These can be in structure, in function, or in behaviour.
- The likelihood of survival, or of reproduction, depends upon those variations.
- A means of inheriting characteristics must exist, so that there is some correlation between the nature of parents and their offspring. Those variations that contribute to the likelihood of the parents' survival will thus most probably be inherited.

It should be stressed that under these conditions evolution is not an option. If any population has these properties then it must evolve. Moreover, the three requirements could be met in many different ways. The variations could be in genetic make-up, or in the ability to understand abstract concepts; the mechanism of inheritance could be social, cultural or genetic," (Barrow, [3], p21). Although Barrow's conditions capture the abstract definition of natural selection, I would like to propose a refined definition which decomposes the concept a little further. I define a collection of objects to evolve by natural selection if and only if they satisfy the following conditions:

1. The objects possess characteristics that vary from one member of the collection to another, ('variable characteristics').
2. All objects in the collection have a finite lifetime.
3. Amongst the characteristics of each object are a special subset which the object retains over its entire lifetime. These characteristics define different types of object in the collection. Let x denote the combined values of the characteristics from this special subset. One can then speak of objects of type x.
4. New objects are created over time.
5. The new objects are reproduced from existing objects in the collection. i.e. Each new object has at least one parent object in the collection.
6. The values of the special characteristics are, at least partially, inherited in reproduction.
7. There is some mutation in the reproduction; the values of the special characteristics are not always copied perfectly from parent to child.

8. The birthrate per capita of objects of type x, and/or the average lifetime of a type x object, is a function of x.

Any collection of objects which satisfies these conditions will evolve by natural selection.

Adaptation to an environment is often equated with evolution by natural selection, but in fact it is not a necessary part of natural selection, and it can be omitted from the abstract definition. In the case of biological evolution, the environment of a species will often determine which species characteristics maximise birthrate and lifetime. In the case of biological evolution, the environment often defines the finite resources which organisms and species compete for. A species population will come to be dominated by those characteristics which maximise birthrate and lifetime, hence, in this sense, a species population will come to be dominated by those characteristics which are optimally adapted to the environment. However, in general it is only necessary to assume that there are variable characteristics, and that the birthrate and lifetime are a function of those variable characteristics. There may or may not be an environment which determines this function. In the case of a collection of universes, there is no environment, and there is no competition between universes for finite resources.

I will now expound Smolin's idea of Cosmological natural selection, showing how his idea satisfies the conditions I proposed above. Hereafter, I shall refer to a collection of universes which are related in some way as a 'population' of universes. Smolin hypothesizes that there exists a population of universes, and that the values of the parameters of physics are variable characteristics of the universes in the population. The values of the parameters of physics are fixed in each universe, but can vary from one universe to another. This is condition (1) and (3) above.

Smolin hypothesizes that certain types of universe in the population are reproductively active. He suggests that in those universes where black holes form, a child universe is created inside the event horizon of the black hole. This is condition (4) and (5) above.

Smolin postulates that the reproduction which takes place is reproduction with inheritance. He suggests that a child universe inherits almost the same values for the parameters of physics possessed by its parent. He postulates that the reproduction is not perfect, that small random changes take place in the values of the parameters. Hence, Smolin postulates reproduction with inheritance and mutation, conditions (6) and (7) above.

The lifetime of a universe is determined by the values of the parameters of physics. The number of black holes in a universe is also determined by these parameters, hence the values of the parameters in a universe determine the number of children born to that universe. Because the values of the parameters are (almost perfectly) inherited by the child universes, the birthrate of a universe type is determined by the values of its parameters. This is condition (8) above.

In addition to the hypothesis that there is a population of universes evolving by natural selection, Smolin suggests that the parameter values which maximise black hole production, and therefore child universe birthrate, are also the values which permit the existence of life. Smolin neglects universe lifetime, and assumes that universe types with the highest birthrate will come to dominate the population of universes. If the universe types with the highest birthrate are also those universes which permit life, then universes which permit life will come to dominate the population of universes.

A Weak Anthropic Principle explanation that imagines a collection of unrelated universes, rather than a population of universes evolving by natural selection, holds that life-permitting universes are *special* members of the collection. In contrast, Smolin's dual proposal that (i) there is a population of universes evolving by natural selection, and that (ii) the parameter values which maximise black hole production are the same parameter values which permit life, holds that life-permitting universes are *typical* members of the collection.

The hypothesis that there is a population of universes evolving by natural selection is distinct from the hypothesis that the parameter values which maximise black hole production are the same parameter values which permit life. One hypothesis could be true, and the other false. Only if both are true will life-permitting universes come to dominate the population of universes. If child universes were created inside black holes with small random parameter variations, and if the parameter values which maximise black hole production were NOT the same parameter values which permit life, then there would be a population of universes which evolve by natural selection, but in which life-permitting universes do not come to dominate the population of universes. The WAP is actually broader in scope here than Smolin's proposal. The WAP is not constrained to imagine a collection of unrelated universes. The WAP can postulate a collection of universe populations, each evolving by natural selection. In such a collection, intelligent life will most probably find itself in those populations in which the parameter values which maximise universe birthrate are the same parameter values which permit the existence of life and intelligent life.

The big problem with Smolin's idea is that a population of objects which satisfies the conditions for natural selection is a very special type of population. There are many different types of population, and a population which evolves by natural selection is a very special type. Most populations of things do not evolve by natural selection. Smolin has provided no reason why a population of universes should be of any particular type. As far as we know, if there is a population of universes, the type of that population is entirely contingent. Smolin's hypothesis requires a very special type of universe population, not a typical one, thereby defeating his overall objective. Thus, even if we do live in a universe population that has evolved by natural selection, and even if the parameter values which maximise child universe creation are the parameter values which permit life, it does not follow that a life-permitting universe is a typical universe. Smolin's argument merely establishes that, given a very special population of universes, a life-permitting universe would be a typical member of that population.

It is either necessary, contingent, or impossible for a universe to create child universes which inherit parameter values with small, random mutations. If it is necessary, then any universe population will evolve by natural selection. If it is impossible, then no universe population will evolve by natural selection. If it is contingent, then some universe populations will evolve by natural selection, and some won't.

In Smolin's scenario, it appears to be contingent for a universe to create child universes. Smolin postulates that the creation of child universes either occurs inside black holes, or at the 'Big Crunch' of a universe which recollapses. Whether or not black holes form, and whether or not a universe will recollapse, is determined by the parameters of physics. Smolin admits that a universe which expands forever, without forming any black holes, cannot create any child universes. If there are universes which do not reproduce, then universe populations consisting entirely of such universes must be universe populations in which reproduction does not take place. If there are universe populations in which reproduction does not take place, then there must be universe populations that don't evolve by natural selection.

Despite this, in his book, 'The Life of the Cosmos', Smolin attempts to create the impression that a universe population necessarily evolves by natural selection. He begins the exposition of his theory by considering a single universe. He admits that "we must restrict the allowed parameters of this initial universe, and all those created from it, so that each one has at least one descendent," ([4], p96). He also admits that "if we create a universe without progeny the process simply stops," ([4], p96). Smolin imagines a linear chain of universes, each of which recollapse, and create a new universe, changing the parameter values on each bounce until finally a universe is created in which black holes form, and the process of natural selection can get underway.

Despite the fact that he fixed the parameter values of the initial universes, we find Smolin claiming that "we began with a single universe with completely random values of the parameters...this one universe has given rise to a vast collection, almost all of which have parameters in the narrow ranges that lead to the production of the most black holes," ([4], p100). Needless to say, Smolin has contradicted himself. He continues, "we did not actually use anywhere the assumption that the universe we began with was the first universe. It might have been any universe in the collection; all that we know about it was that its parameters were chosen randomly. What this means is that any universe in the collection, no matter what its own parameters are, is likely to spawn in time a vast family of descendants that after a while are dominated by those whose parameters are the most fit for producing black holes. No matter what assumptions we make about the collection of universes at some earlier time, it will always be the case that after a sufficient time has passed, almost all of them have parameters in the narrow range that produce the most black holes," ([4], p100).

This argument is totally false for the reason Smolin has already acknowledged himself: some universes have no progeny. A population of universes which contain only universe types that have no progeny cannot evolve by natural selection. Contrary to Smolin's assertion, it matters very much what assumptions we make about the collection of universes at some earlier time. Even if we accept Smolin's postulate that child universes are created inside black holes, there will be universe populations that do not evolve by natural selection. If we reject his postulate that child universes are created inside black holes, then this conclusion is reinforced.

Smolin argues that we "do not need to assume that all universes have at least one progeny. Whatever the details of the ensemble at earlier times, our existence shows that there was at least one line of descent that never died out. Nothing is lost if we admit the possibility of choices of parameters that give rise to universes, which expand forever but never make black holes," ([4], p101). This is complete nonsense. The declared objective of Smolin's theory is to explain why a life-permitting universe exists, given that such a universe appears to be contingent. If a certain type of universe population evolves by natural selection to produce life-permitting universes, but other types of universe population do not, then there is a need to explain why one contingent type of universe population exists, rather than another. When Smolin faces the question, 'Why does this type of universe population exist?' he effectively gives the answer 'because we are here'. This answer does not explain the contingency. Our existence does show that a life-permitting universe exists, but the point is that it could have been otherwise. If the type of universe population that exists is contingent, then there might not have been a 'line of descent that never died out'.

If Smolin's postulate that child universes are created inside black holes with small random parameter mutations, is correct, then a population that contains some black hole producing universes, will probably evolve by natural selection. In particular, a population with an exhaustive, initially uniform distribution of parameter value combinations, will come to be dominated by universes that maximise the production of black holes. However, either type of population is a contingent type of universe population. Moreover, if Smolin's postulate is incorrect, then even these types of universe population will not evolve by natural selection.

Not only is a population of universes which evolves by natural selection contingent, but it is also extremely non-typical. There are many ways in which a population of universes might not evolve by natural selection.

For a start, Smolin tacitly assumes that the basic ontology of a universe must be similar to the ontology of our own universe. Smolin assumes that within a population of universes, the same basic types of thing will exist. Although he suggests that the values of the parameters of physics will vary from one universe to another, he assumes that the same parameters of physics will be found in all the different universes. The ontology of a universe could be different from our own in the sense that it could contain different types of objects and properties. There could, for example, be no such thing as a photon or an electron. There could be no such properties as mass-energy, or electric charge, or angular momentum. There might be no such thing as space-time.

If there were no such thing as light (the photon), then there could be no such thing as the speed of light, one of the parameters of physics. If there were no such thing as the electron, then obviously, there could be no such thing as the charge of the electron. If there were no such thing as space-time or mass-energy, then there could be no such thing as gravitation, hence there can be no such thing as a gravitational constant. It might be impossible to compare the parameters of different universes because the parameters might be parameters of different types of thing. There might even be no such thing as parameters in universes with a different ontology.

A universe with one ontology could conceivably give birth to a universe with a different ontology, in which case the inheritance of parameter values would have no meaning. Natural selection is dependent upon inheritance, hence a population of universes with ontology variation could not evolve by natural selection.

If universes with a different ontology to our own are possible, then a universe population in which each universe has the ontology of our own universe might well be a very special type of universe population. Moreover, life-permitting universes might only be possible in a universe population with the ontology of our own universe.

Even within those universe populations which have the same ontology as our own universe, and which therefore have the parameters of our own universe, there are many ways in which a population might fail to evolve by natural selection:

1. The values of the parameters of physics might be variable in the population, but there might be no universe reproduction.

2. There might be universe reproduction, but the values of the parameters of physics might not be variable in the population.

3. The values of the parameters might be variable in the population, and there might be universe reproduction, but the number of child universes that a parent universe creates, and the lifetime of a universe, might be independent of the values of the parameters of physics. In other words, each universe type could give birth to the same number of child universes, and each universe type could have the same lifetime.

4. The values of the parameters might be variable in the population, there might be universe reproduction, and the number of child universes that a parent universe creates might be determined by the values of the parameters of physics in the parent universe, but there might be no inheritance in the reproduction. In other words, the values of the parameters of physics in a parent universe might not be inherited by the child universes which the parent creates. If the characteristics which determine birthrate and lifetime are not hereditary, then natural selection cannot take place. Even if a particular universe type created a large number of child universes, the parameter values in all the children would tend to be different from the parent and from each other. A universe type which created a large number of child universes would not come to dominate the population. There

would be no change in the fraction of the population occupied by each universe type. A universe type which creates a large number of child universes will come to dominate a population only if it creates child universes of its own type.

5. The values of the parameters might be variable in the population, there might be universe reproduction, the number of child universes that a parent universe creates might be determined by the values of the parameters of physics in the parent universe, and the values of the parameters of physics in a child universe could be inherited from the values of the parent, but if there is no mutation in the reproduction, then natural selection cannot take place.

Suppose one had a population of universes as described in case (3). In such a population, the parameters of physics vary between the different members of the population, universe reproduction takes place, but the number of child universes that a parent universe creates, and the lifetime of a universe, is independent of the values of the parameters of physics. Suppose, in addition, that the values of the parameters of physics are inherited with occasional, random mutation. Such a population will evolve, but it will evolve randomly, and not by natural selection. The frequency of characteristics will change in the population, and in this sense the population evolves. The random mutations that occur in reproduction entail that the relative frequency of the different characteristics will change randomly. However, because there are no characteristics which maximise birthrate or lifetime, the population will never be dominated by any particular characteristics. As far as we know, a population of universes could satisfy these conditions, not the conditions for natural selection. A population of universes might never be dominated by any characteristics, and in particular, would never be dominated by life-permitting universes.

Consider a collection of objects in which (i) there are variable characteristics within the collection, (ii) all objects in the collection have a finite lifetime, (iii) new objects are created in the collection, but in which (iv) the new objects are not reproduced from existing objects in the collection. i.e. New members of the population are born without having any parent or parents in the existing population. Suppose in addition that (v) new objects of each type are created at the same rate, but (vi) the lifetime of an object is determined by its type. i.e. lifetime is determined by the values of the variable characteristics. Such a population evolves to be dominated by the long-lifetime objects. This is neither random evolution, nor evolution by natural selection.

The population of stars in a galaxy comes close to satisfying the conditions to be a population of this type. The mass and chemical composition of different stars vary, and these are the characteristics which determine the lifetime of a star. The smaller the mass of a star, the longer its lifetime. New stars are continually born, but they are not born from other stars, they are born from the Giant Molecular Clouds of the interstellar medium, and consequently the mass of a new star is not inherited. The lifetime of every star is finite. The birthrates of the stars of different masses and chemical compositions is approximately constant. Hence, the low mass, long lifetime stars come to dominate the population of stars in a galaxy.[2]

A population of universes could be a population of this type, with new universes being born, but not by reproduction from other universes. Such a population of universes would be dominated by long-lifetime universes, not by those which permit life.

Smolin's theory is not inadequate merely because it fails to establish that the existence of a life-permitting universe is necessary; it also fails to establish that the existence of a life-permitting universe is even probable. If a universe population that supports evolution by natural selection is a very special type of universe population, then those universe populations that support evolution by natural selection constitute a very small fraction of the collection of all universe populations. If a universe population is randomly chosen, then the probability is very small that it would be a universe population which supports evolution by natural selection. If the probability of a universe population which supports evolution by natural selection is very small, then the probability of a life-permitting universe is very small.

At best, Smolin has merely established a conditional probability: given the existence of a universe population which supports evolution by natural selection, there is a high probability that a life-permitting universe will exist. Even this conditional probability is dependent upon Smolin's postulate that the parameter values which maximise black hole production are the same parameter values which permit life.

The anthropic principle does not place such stringent requirements upon the collection of postulated universes as Smolin's theory of Cosmological natural selection. The anthropic principle postulates a collection of universes which possess characteristics that vary from one member of the collection to another, but it does not require universes which are capable of reproduction, inheritance of characteristics, or random hereditary mutations. The anthropic principle does, however, require that the collection of postulated universes contain at least some which are life-permitting. This condition could be satisfied by a collection of unrelated universes which contain some life-permitting members, or it could be satisfied by a collection which contains at least some sub-collections of related universes, ('populations'), which are evolving by natural selection *via* black hole genesis, and in which the parameter values which maximise black hole production are the same parameter values which permit life.

Whilst the anthropic principle is broader in scope than Smolin's hypothesis, it doesn't work with an arbitrary universe collection, which might not contain

[2]The chemical composition of the interstellar medium in a spiral galaxy is changing with the passage of time. The material expelled from one generation of stars provides a high-metallicity contribution to the medium from which the next generation of stars is composed. High metallicity inhibits the formation of higher-mass stars, hence the relative birthrate of lower-mass stars in a spiral galaxy increases with the passage of time. The eventual domination of lower-mass stars is therefore the consequence of both statistics and the physics of star formation processes.

any life-permitting members at all. A randomly chosen universe collection is not sufficient to guarantee the existence of life. The anthropic principle does not explain why the universe collection that purportedly exists is the special type of collection which contains life-permitting universes. If the type of universe collection that exists is contingent, then why is the collection-type which exists the type which permits life in at least some members?

Advocates of the anthropic principle might postulate that an exhaustive, randomly infinite collection of universes exists. A universe collection is exhaustively, randomly infinite if each type of universe exists, and there is a uniform distribution of the different universe types. For those universe types which have the ontology of our own universe, and therefore have the parameters known in our own universe, there would be a uniform distribution of the possible parameter value combinations. An exhaustive, randomly infinite collection will necessarily contain life-permitting universes. If such a collection contains an infinite number of instances of each universe type, then it is the maximal collection, the collection which contains all others as sub-collections.

Given an exhaustive, randomly infinite collection, Smolin could argue that it would come to be dominated by life-permitting universes, because those sub-collections of related universes which are evolving by natural selection *via* black hole genesis, and in which the parameter values which maximise black hole production are the same parameter values which permit life, would come to dominate the overall collection.

However, postulating either an exhaustive, randomly infinite collection, or even the maximal collection, does not avoid the problem of contingency. The existence of such inclusive universe collections is just as contingent as the existence of a more exclusive collection. Why should an exhaustive, randomly infinite collection exist, rather than a much smaller exclusive collection, in which there are no life-permitting universes? Both the anthropic principle and the theory of Cosmological natural selection fail to deal with the contingency in the type of universe collection. Both hypotheses provide conditional explanations of why the contingent parameters of physics possess the special values that we observe them to possess, but both theories fail to justify the postulation of a special type of universe collection.

References

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