On the likelihood of habitable worlds

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The anthropic principle has gained much popularity among cosmologists. But, faced with a need for historical explanation, biologists are bound to find it a cop-out.

THE anthropic principle suggests that physical laws can be explained by the fact that they have given rise to intelligent observers, able to discuss their nature. The idea has gained considerable popularity among cosmologists, but biologists are bound to have reservations. If it is true that "we are here because we are here", the study of evolutionary transitions becomes the study of the trivial or the futile. We suggest that the main merit of the anthropic principle may be that it has aided the appearance of other, potentially more useful, approaches to the problem of the likelihood of habitable worlds.

The idea that the world is peculiarly adapted to the appearance of life is not a new one. In 1913, the biochemist L. J. Henderson[1] pointed out that many substances such as water have precisely those properties required if life is to exist. Most biologists rejected his views, arguing that organisms are adapted to their environments by natural selection, not the other way around. But the questions he raised have surfaced again recently in a new form. It turns out that the physical constants have just the values required to ensure that the Universe contains stars with planets capable of supporting intelligent life. The 'cosmological anthropic principle'[2] has been suggested as an explanation for this puzzling fact.

The principle takes several forms. The weak anthropic principle merely states that certain universes, with unfortunate lists of physical constants, would not be observable by us, simply because we would not be there. The weak principle is not a theory: it merely acknowledges a peculiar situation.

The strong principle, proposed by Brandon Carter[3], is more radical. It states that the Universe *must* have those properties that allow life to develop in it at some stage of its life history. How can this curious claim be understood? The simplest interpretation is that the Universe was designed by a creator who intended that intelligent life should evolve. This interpretation lies outside science. Within science, there are two possibilities. First, there is only one universe possible on logical grounds, and the list of constants follows from a (so far unavailable) 'theory of everything'. Second, there are indeed many possible alternative universes. If so, the presence of observers may have a crucial role, since, according to the Copenhagen interpretation of quantum physics, it is the act of observation that chooses among possible superpositions. This version depends on the perhaps unjustified assumption that Schrodinger's equation can be applied to macroscopic objects. It also seems to lead to the rather odd conclusion that the wave function did not collapse until the recent evolution of conscious observers on Earth, or perhaps elsewhere in the Universe.

We acknowledge the value of the weak anthropic principle in putting a constraint on cosmological theories: some models are incompatible with our very existence. But this is not the same as an 'explanation' of physical laws, at least as the word is commonly used. To explain an event is to give a cause for that event. This is the sense in which the word is used in the biological sciences, although perhaps not in physics. Of course, an event may have several causes. That the heart beats requires both a physiological explanation, in terms of the properties of muscles and nerves, and an evolutionary explanation, in terms of natural selection for efficient transport. The strong anthropic principle seems to be an explanation in this causal sense, asserting that intelligent beings *must* come into existence. The assertion is essentially unproved, and unlikely to be true. If we had to come about anyway, then analysis of evolution, seen from this high level of 'explanation', is almost irrelevant.

Evolutionary biology is a historical science. It tries to explain past events in terms of a theory (natural selection — that is, the dynamics of populations of entities with variation, multiplication and heredity). To explain a particular event, say the origin of the eukaryotes, is to show that, given plausible initial conditions, the event, if not inevitable, was at least reasonably likely. The explanation should also be supported by evidence: the symbiotic theory of the origin of the eukaryotes is supported by the presence in mitochondria of DNA and a bacteria-like translating machinery. It would be unsatisfactory to argue that, because eukaryotes are in fact here, then any accidents, however unlikely, needed to give rise to them must have happened.

As biologists, we are unhappy with the anthropic principle because, faced with a need for historical explanation, it seems to be a cop-out. We are correspondingly attracted by Smolin's recent suggestion[4] that the values of the physical constants can be explained by a process of cosmological natural selection. The central idea is that the formation of a black hole is equivalent to the formation of a new 'universe', causally isolated from the 'parent' universe. The word 'universe' is here being used to mean not 'everything there is' but a causally isolated system. If, as J. A. Wheeler has suggested, the laws of nature in the new universe differ by a small amount from those in the parent, we have the properties of variation, multiplication and heredity needed for natural selection. The 'fitness' of a universe — the property maximized by selection — is the number of black holes produced. Smolin predicts that any small change in the constants should reduce (or leave unchanged) this number. The physical constants needed to maximize the production of black holes correspond, roughly, to those needed for the appearance of stars, planets and perhaps observers. So the theory offers a causal explanation for the fact that the constants are peculiarly adapted for the appearance of intelligent life.

We can see some difficulties. Most seriously, models of natural selection in biology always assume that the total population size is limited (by space, nutrients or what have you), an assumption true of real populations, except for short periods of time. A population of causally isolated universes would not be limited. In Smolin's model, even inferior universes, with a smaller productivity of black holes, multiply exponentially, even though they constitute an ever-decreasing proportion of the whole population. So given two types of universe, with different productivities of black holes and hence different Malthusian fitnesses, both would multiply exponentially, and reach infinite numbers in infinite time, but the proportion of the fitter type would approach unity. If the physical constants needed to produce black holes also favour the appearance of life, then the probability that a random universe will be favourable for life will also increase. □

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