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THE SAP ALSO RISES: A CRITICAL EXAMINATION OF THE ANTHROPIC PRINCIPLE

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I conclude from these accidents of physics and astronomy that the universe is an unexpectedly hospitable place for living creatures to make their home in. Being a scientist trained in the habits of thought and language of the twentieth century rather than the eighteenth, I do not claim that the architecture of the universe proves the existence of God. I claim only that the architecture of the universe is consistent with the hypothesis that the mind plays an essential role in its functioning.

—F. Dyson, *Disturbing the Universe*

THE Anthropic Principle ("AP" for short) is to be found at work in leading scientific journals—*Nature, The Astrophysical Journal, Journal of the Royal Astronomical Society, Philosophical Transactions of the Royal Society, Observatory*, among others. It has been used by a not insignificant percentage of the who's who of relativistic astrophysics—Dicke, Carter, Hawking, Ellis, Barrow, Silk, to name a few. It has, not surprisingly, found its way into the semi-popular and popular literature, with articles appearing in such journals as *Sky and Telescope*, *Scientific American*, and *Psychology Today*. It has also attracted the interest of philosophers of science because anthropic reasoning has been seen as holding the promise of a new methodology of scientific explanation that places Man (or perhaps Consciousness or Observership) at the center of our understanding of nature.[1]

The enthusiasm of the proponents of the AP is matched by the trenchancy of the critics. Heinz Pagels (1985) has charged that the AP is "an unscientific idea," that it "has no place in physics or cosmology," that it "makes no progress towards solving the great mysteries of the universe," and that it "confronts us with a new mystery: How can such a sterile idea reproduce itself so prolifically?" And Martin Gardner (1986), reviewing Barrow and Tipler's encyclopedic work, *The Anthropic Cosmological Principle*, charges that their "FAP" (short for future anthropic principle) is more accurately dubbed "CRAP" (completely ridiculous anthropic principle).

The truth lies not so much between as outside the extremes of the proponents and the critics. On one hand, anthropic reasoning does not deliver on the promise of a new methodology of scientific explanation; but neither, on the other hand, is the AP an unscientific idea which has no place in physics or cosmology. Sifting the truth is no easy matter since even a casual glance at the rapidly expanding literature reveals that the AP is not a single, unified principle but rather a complicated network of postulates, techniques, and attitudes. Faced with such a diversity of ideas and conflicting claims about their usefulness and validity, it seems best to begin by trying to understand the motivation for and meaning of the AP as it was first introduced by Dicke and Carter.

1. THE WEAK ANTHROPIC PRINCIPLE ("WAP") OF DICKE AND CARTER

. . . we must be prepared to take account of the fact that our location in the universe is *necessarily* privileged to the extent of being compatible with our existence as observers. (Carter 1974, p. 293)

[T]he observed values of physical variables are not arbitrary but take values $V(x,t)$ restricted by the spatial requirement that $x \in L$, where L is the set of sites able to sustain life; and by the temporal constraint that t is bounded by time scales for biological and cosmological evolution of living organisms and life-supporting environments. (Barrow 1983, p. 147)

The observed values of all physical and cosmological quantities are not equally probable but they take on values restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirement that the Universe be old enough for it to have already done so. (Barrow and Tipler 1986, p. 16)

Sifting through the portentous language of these statements of WAP, it is hard to find anything stronger than a tautology. How then can Carter, who coined the term "anthropic principle" say that "a prediction based on the *weak* anthropic principle (as used by Dicke) can amount to a complete explanation" (1974, p. 295)? Gale issues the mild demurrer that WAP "just isn't *satisfying* as an explanation" (1986, p. 106). But if WAP is vacuous, how can it be the source of any explanation at all? The answer is that WAP, as originally introduced by Dicke and Carter, is not a claim or part of a proper explanation. It is simply a special case of a familiar principle for judging the bearing of evidence on theory.

This interpretation of WAP emerges clearly from Dicke's (1961) and Carter's (1974) treatment of one of the famous 'large number coincidences' of cosmology that says that

$$ct_o/a_o \simeq \alpha/\alpha_G \simeq 10^{37} \qquad (1)$$

where t_o is the Hubble age of the universe, $a_o \equiv \hbar^2/m_e e^2$, $\alpha \equiv e^2/\hbar c$, and $\alpha_G \equiv Gm_p/\hbar c$. Dirac (1937, 1938) was so struck by this coincidence that he postulated (T_D) that, in opposition to the standard big bang cosmology (T_{BB}), the gravitational coupling constant is not really a constant but varies as the universe expands so as to maintain (1) throughout all time. Dicke's criticism of Dirac is a variant of the commonsensical observation that finding fishes exclusively of lengths six inches and greater is not good evidence that all the fish in the sea are longer than six inches if the nets used are not fine enough to hold smaller fish.

Applying the lesson to the case at issue, the coincidence (1) does not, as the following superficial analysis seems to suggest, make T_D more likely than T_{BB}. If $C(1)$ is the evidence that (1) is now true, then (superficially)

$$\begin{aligned} &Pr(C(1)/T_D) \simeq 1 \\ &Pr(C(1)/T_{BB}) << 1 \end{aligned} \qquad (2)$$

Thus, if T_D and T_{BB} are given roughly equal prior probabilities, it follows from Bayes' theorem that

$$Pr(T_D/C(1)) >> Pr(T_{BB}/C(1)) \qquad (3)$$

But, Dicke and Carter respond, our probability calculations should take into account the fact that our observing (1) imposes a selection effect no less than does the size of the mesh of the fish net. One way to model the selection effect is to use a modified probability measure $Pr_s(\cdot) \equiv Pr(\cdot/L)$ where S stands for selection and L is the proposition that life such as ours now exists. Dicke and Carter then make it plausible that $Pr_s(C(1)/T_{BB}) \simeq 1$, with the upshot that $C(1)$ gives no reason to prefer T_D to T_{BB}.

Actually there is no need to define special selection functions if one works within standard Bayesian epistemology which demands that probabilities be computed on the basis of the *total* evidence. Suppose that E_{tot} consists of the conjunction of $C(1)$, the observed coincidence (1); L, the proposition that life such as ours now exists; and B, the background evidence. By the multiplication axiom of probability,

$$\begin{aligned} Pr(C(1)\&L\&B/T) = \; & Pr(C(1)/L\&B\&T) \\ & \times Pr(L/B\&T) \times Pr(B/T) \end{aligned} \qquad (4)$$

Following the Dicke-Carter analysis, we assume that $Pr(C(1)/L\&B\&T_D) \simeq Pr(C(1)/L\&B\&T_{BB}) \simeq 1$. And to simplify matters we also assume that $Pr(B/T_D) \simeq Pr(B/T_{BB})$. Thus, if the prior probabilities of T_D and T_{BB} are roughly the same, then Bayes' theorem implies that the posteriors on E_{tot} will also be roughly the same, unless one of the theories makes the emergence of life more likely than does the other.

The last caveat is an important one since it tends to be neglected in WAP arguments. Consider, for example, the WAP objection to the steady-state cosmology (T_{ss}) of Bondi, Gold, and Hoyle. On T_{BB} it is no surprise that the Hubble time t_o is of the order of the age of a typical star whereas on T_{ss} it is surprising since on T_{ss} there is a continuous creation of matter and thus there is no reason why the timescale for stellar evolution should not be either much less than t_o or else much greater (see Barrow and Tipler 1986, p. 17). But this difference can be compensated if $Pr(L/B\&T_{ss}) >> Pr(L/B\&T_{BB})$, which is not implausible since a steady state universe can be expected to contain many locations supportive of carbon-based life while the same expectation is not warranted for a typical big bang universe.[2]

This brief overview of WAP suffices to establish the following points.

(i) Gale offers this assessment of Dicke's procedure:

> Deductive or predictive logic proceeds from a fundamental assumption to a derived result: the future is deduced from the past. The temporal flow of Dicke's argument is in the opposite direction. He cites a present condition (man's existence) as the explanation of a phenomenon grounded in the past (the age of the universe). Clearly his result cannot be interpreted as a prediction, since it would be a prediction of the past on the basis of that past's own future. (1981, p. 157)

But Dicke was not proposing an explanation, properly speaking, of (1), and there is nothing in his or Carter's use of WAP to justify intimations of teleology. The closest Dicke and Carter get to an explanation is to *explain away* whatever surprise one might naively have felt upon discovering (1).[3]

(ii) It is a nice rhetorical flourish to oppose the (perhaps) too fashionable Copernican Principle, according to which man must not be assumed to occupy a privileged central position, with the Anthropic Principle, according to which our situation in the universe must be privileged to the extent required by the conditions for our existence (Carter 1974, 1976). But the rhetoric is potentially misleading since the motivating force of WAP, in the sense explicated above, does not derive from any consideration about Man, Consciousness, or Observership. WAP, as used by Dicke and Carter, is in fact nothing but a corollary of a truism of confirmation theory. Nor does the application of the corollary have to rely on life or minds, for the selection function is served just as well by the existence of stars and planetary systems supporting a carbon-based chemistry but no life forms.[4] (Of course, if there were no conscious observers there would be no one to raise questions which the WAP is supposed to answer. But that truism hardly heralds any special role for observers in cosmology since similar truisms resound throughout the corridors of every scientific discipline.) Nor does generic life or generic consciousness serve the selection function, at least not if non-carbon based life forms are possible in big bang universes.

Before closing this section it should be noted that much interesting physics and ingenious argumentation is used by Dicke, Carter, *et al.* in establishing the plausibility of $Pr(C(1)/L\&T_{BB}) \simeq 1$ and the like. This is the non-trivial content of WAP methodology. The cleverness of the arguments helps to explain why the AP has attracted some of the brightest minds in relativistic cosmology. But brilliance has not made these minds proof against the seductive idea that there must be an overarching Principle which transmutes the arguments from the merely clever into the profound. Some of the consequences of this self-seduction are described in the following sections.

2. The Strong Anthropic Principle ("SAP")

> . . . the Universe (and hence the fundamental parameters on which it depends) must be such as to admit the creation of observers within it at some stage. (Carter, 1974, p. 294)
>
> . . . intelligent life *must* evolve somewhere in any physically realistic universe. (Tipler, 1982, p. 37)
>
> . . . the Universe must contain life. (Barrow, 1983, p. 149)
>
> The Universe must have those properties which allow life to develop within it at some stage in its history. (Barrow and Tipler, 1986, p. 21)

There are significant differences within this sample of formulations of SAP, but whether and how the differences matter depends upon the uses to which SAP is to be put. Carter, who first distinguished in print between weak and strong versions of the anthropic principle, talks of using SAP for explanations; for example, he speaks of promoting "a *prediction* based on the strong anthropic principle to the status of an *explanation* by thinking in terms of a 'world ensemble'" (1974, p. 295). I will return to the topic of explanation in Sec. 4, but for the moment I emphasize that, as I read Carter's program, the primary animus for both WAP and SAP is not a search for explanation (in any of the standard senses of that term as used in the philosophy of science literature) but a desire to preserve standard big bang cosmology via a selection-effect ploy. WAP sufficed in the face of the coincidence (1). But there are other coincidences and improbabilities which apparently call for an extension of the selection-effect notion.

Thus, consider the facts that the measured expansion rate of the universe is almost exactly equal to the critical rate which separates eternal expansion from recontraction and that, on a large scale, our universe is very isotropic. On T_{BB} this might seem, *a priori*, to be amazing. For (the story goes), if we were to define a reasonable normed measure on the ensemble $\mathcal{W}$ of all big bang models, we would expect that the subensemble $\mathcal{F}$ of models exhibiting the features in question would get tiny measure. Nevertheless, T_{BB} can be defended in a manner that is (apparently) parallel to the argument of Sec. 1; namely, we could argue that the existence of organisms describable as observers is possible only within a limited subensemble C of cognizable worlds and that, relative to C, $\mathcal{F}$ has large measure. More formally, if μ is the measure on the world ensemble $\mathcal{W}$ and $\mu(\mathcal{F} \cap C) \neq 0$, then we can work with the selection measure $\mu_s(\cdot) \equiv \mu(\cdot/C)$ and try to show that $\mu_s(\mathcal{F}) \simeq 1$. (If $\mu(\mathcal{F} \cap C) = 0$, a more elaborate ploy is needed.)

But how exactly is the measure μ connected with probability? Consider the case of a coin flipping experiment with independent trials and a constant probability $0 < p < 1$ for heads. Let $\mathcal{W}$ now stand for the collection of all possible outcomes of the experiment (i.e., all infinite sequences of heads and tails) and let μ be the Bernoulli measure on $\mathcal{W}$. Then if $\mathcal{F}$ is the collection of all sequences in which, say, the relative frequency of heads fails to approach the limit p, $\mu(\mathcal{F}) = 0$ which can be interpreted as asserting that the probability that the coin flipping apparatus will produce a sequence with this feature is 0. In the case of cosmology, however, we have to work to create a parallel interpretation for μ. Consider a Cosmic Dart Board. The points of the Board are to correspond one-one to the elements of $\mathcal{W}$ in such a way that the spatial measure of an area A of the Board is equal to the μ-measure of the corresponding set $\mathcal{A}$ of worlds. Thus, if the dart is thrown randomly at the Board, the probability that the point hit corresponds to a world exhibiting the features in question will be $\mu(\mathcal{F})$. Finally, if the Creator decides which big bang model to actualize by the random dart method, then the probability of actualization of a universe having the features observed in our universe is nil.

But if that is the connection between small μ-measure and the 'improbability' of various features of our universe, then the improbability is not explained away by a selection principle which shows that $\mu_s(\mathcal{F}) \simeq 1$ —unless the creation story is changed so that the Creator does not fire his dart at random but with the sure aim of hitting somewhere within the area corresponding to C. Of course, it is just as easy and somewhat simpler to posit a Creator who ignores C and aims directly at the area corresponding to $\mathcal{F}$. I leave it to the theologians and metaphysicians to decide which mode of operation the Creator is more likely to adopt. Whatever the decision. this much is clear. If one adopts a creation story of actuality and if one calculates that the probability of creation of a big bang model having the features in question is nil, then no anthropic principle, construed as a selection principle, is going to resolve the problem. The resolution calls rather for something akin to the traditional argument from Design.

Alternatively, the need for a creation story of actuality and the need to wrestle with improbabilities of actualization can be obviated by treating actuality as a token-reflexive property of possible worlds not unlike the "nowness" property of instants of time (see Lewis 1986). On this view all possible worlds, including the merely logically possible as well as the physically possible, are all equally "actual." No Creator is needed to anoint one of these worlds with the magical property of "actuality" and the question of why this property was conferred upon a world having the features in question is mooted.

In sum, either there is no problem about the improbability of actualization, or else there is; in the former case no AP is needed, and in the latter case no AP operating as a selection principle à la Dicke and Carter solves the problem.

The second horn of this dilemma can be grasped by interpreting SAP not merely as a selection principle in the sense discussed above but as a "reality principle" which asserts that no world can be "real" or "actual" unless it contains life and observers or at least features which make possible the existence of organisms describable as observers. This interpretation is suggested by the formulations of SAP by Barrow and Tipler quoted above. It is also an interpretation which Gale (1981) attributes to Carter, but Carter (1983) explicitly disassociates himself from it. Quantum considerations, especially the quantum description of the measuring process, might be used to support the idea of an inextricable link between actuality and a conscious observer, but this takes us beyond SAP to PAP (the participatory anthropic principle), which will be discussed in Sec. 3 below.

One might seek to rejuvenate worries about improbabilities by switching the focus of concern from the improbability of actualization to the improbability of observation. One might argue, now using μ as a guide to probability of observations, that on big bang cosmology the probability of observing the features in question is nil—in the notation of the previous section $Pr(F/B\&T_{BB}) \simeq 0$. But this means of connecting μ with probability is even less attractive than the one examined above. The idea of actuality being decided by a random throw at the Cosmic Dart Board is wildly metaphysical but at least it is coherent. The idea that our observations represent a random sample from $\mathcal{W}$ is literally nonsensical; for if the standard theory of big bang cosmology T_{BB} is correct, we inhabit one of the models of $\mathcal{W}$ and all of our observations are made within that model.

There are two ways to respond. The first is to appeal to an initial "veil of ignorance," the idea being that since we do not have any *a priori* reason to think that we inhabit one rather than another of the elements of $\mathcal{W}$, the *a priori* probability of an observation should be calculated on the assumption that the observation is being made *as if* it were a random sample of $\mathcal{W}$. But if it is ignorance which generates puzzlement about improbabilities, then there is an easy solution. "Remove the veil of ignorance" is an injunction that doesn't require the backing of an AP, strong or weak.

The second response imagines that when the veil of ignorance is lifted what is revealed is not that our universe is an element of $\mathcal{W}$, i.e., a standard big bang world, but a superworld that contains within itself counterparts of various elements of $\mathcal{W}$. If these counterparts represent a random sample of $\mathcal{W}$, then the *a priori* probability of finding, within our worlds-within-worlds universe, the features in question is not 1 but nil. But any puzzlement we might have felt at the fact that we observe such features can be dispelled by realizing that such features are virtually certain within the subset of cognizable mini-worlds.

Notice where this worlds-within-worlds scenario leads. First, SAP has given way to a somewhat broadened version of WAP which extends the original selection effect idea from temporal stages of a standard big bang world to spatio-temporal stages of a superworld. Second, however, the use of superworlds seems to undercut the raison d'être of WAP as originally introduced by Dicke and Carter—namely, the defense of standard big bang cosmology. This tension in Carter's writings is resolved by later writers who cut anthropic reasoning free of its original purpose and promote it to the status of a new source of explanation. But before turning to these later views, it should be remarked that the anthropic literature contains two speculations for building superworlds that would allow Carter to have a large slice of his cake and eat it too. I will argue that both speculations are beyond the pale of plausibility.

Wheeler (1973, 1977) has imagined an oscillating model in which many standard big bang models are strung together: the universe expands from a big bang, recollapses to a singularity, expands again, etc. ad infinitum. It is envisioned that the different "cycles" have randomly different expansion rates, randomly different degrees of isotropy, etc. There are two difficulties with this scenario. First, if the expansion rate of a "cycle" is sufficiently great, recollapse will not take place and the scenario will destroy itself. Secondly, and more fundamentally, from the perspective of classical general relativity theory the different "cycles" might as well be different possible worlds. A causal curve approaching a big bang singularity cannot be continuously extended through the singularity, and at present we have no principles to indicate what non-continuous extensions should and should not be allowed. The singularities thus separate our cycle from the others just as effectively as topological disconnectedness. It may be that combining quantum physics with general relativity provides a means for the universe to 'bounce' at the point where expansion is exchanged for contraction without generating singularities that rend the fabric of space-time and effectively disconnect us from the other cycles. But that is pure speculation. That anthropic theorists stand ready to make use of any such speculation which proves handy tells us something about their methodology.

A more favored means of generating supermodels, and the one mentioned by Carter himself, relies on the Everett many-worlds interpretation of quantum mechanics (QM). Those innocent of the controversies about the problem of measurement in QM should be chary of pronouncements by anthropic theorizers to the effect that the Everett interpretation is virtually dictated by the internal logic of QM and that it is the only interpretation viable in quantum cosmology. A recent symposium could reach no agreement on whether the Everett interpretation yields an acceptable solution; nor was there even agreement on what this interpretation is (see Geroch 1984, Healey 1984, and Stein 1984). Moreover, the appeal to cosmology provides only a pseudo-motivation. With only mild caricature the argument amounts to this. On the orthodox interpretation of quantum measurement a clash occurs when we try to apply QM to cosmology. Von Neumann's Process 1 (reduction of the wave packet) requires an external observer; but in cosmology the object system is the universe as a whole so that there is no place for an external observer to stand. This is a pseudo-problem, for Process 1 does not require an external observer in the sense of an observer spatially outside of the object system but rather in the sense that the combined object + observer system is not correctly described by Process 2 (Schrödinger evolution).

The real and interesting motivation for the Everett interpretation has nothing to do with cosmology *per se*; it is the desire to dispense with Process 1 altogether in favor of the universal validity of Process 2. Note, however, that in Everett's (1957) original formulation this goal was to be achieved not by multiplying worlds but by a relative state interpretation of the wave function according to which the constituent subsystems of a composite system generally do not have definite states independent of one another. Thus, there is supposed to be only one physical system representing the observer; but after interaction with the object system there is no single unique state of the observer but rather many different observer states cum object states (e.g., live cat state coupled with observer seeing live cat, dead cat state coupled with observer seeing dead cat). An obvious problem with this description is that since, after measurement interaction, the observer knows that he is in a single unique state (e.g., seeing dead cat), the observer cannot be identical with his body. Rather than swallow this consequence some theorists prefer to have the physical system split into different copies, one for each term in the superposition (e.g., a system in which there is a live cat and an observer seeing a live cat, and a system in which there is a dead cat and an observer seeing a dead cat—see DeWitt and Graham 1973). In order that such a many-worlds picture be consistent with, for instance, the perceived absence of multiple Coulomb forces (imagine an electrically charged cat), the space-time itself must presumably split into branches which are topologically disconnected after the measurement is made. The miracle of Process 1 on the orthodox interpretation is replaced by the new miracle of the splitting of space-time. Not only is there no hint as to what causal mechanism would produce such a splitting, there is not even a characterization of where and when it takes place. If the establishment of a correlation between the object system and measuring apparatus were sufficient for measurement then systems would be continuously undergoing Process 1 collapse (on the orthodox interpretation) or splitting (on the many-worlds interpretation). The fact that they are not and what more is needed for Process 1 or splitting to come into play are left unexplained by both interpretations.

Even if we set aside such qualms and go on to imagine that the wave function of the entire universe is a superposition over counterparts of the virtual ensemble $\mathcal{W}$ of standard big bang models, we are still faced with the puzzle of how, without the help of Design, the expansion coefficients in the superposition manage to arrange themselves so as to produce just the right probabilities.

There are other ways to build supermodels, but they involve radical revisions in standard big bang cosmology. Some anthropic theorizers seem all too eager to embrace any form of world making that gives purchase to their modus operandi. Before turning to this matter I will review two other forms of the AP.

3. PAP and FAP

In a 1977 article, Wheeler asked:

> Is it his indispensable role in genesis that is some day to explain the otherwise so mysterious centrality of the 'observer' in quantum mechanics? Is the architecture of existence such that only through 'observership' does the universe have a way to come into being? (1977, p. 7)

Wheeler's own answer was cautious:

> To advocate the thesis of 'genesis through observership' is not the purpose here; nor is it the purpose to criticize the thesis. It is too frail a reed to stand either advocacy or criticism. (1977, p. 8)

Excessive caution is not one of the faults of anthropic theorists. And in fact Wheeler's frail reed was converted into a Principle:

> (PAP) Observers are necessary to bring the universe into being (Barrow 1982, p. 150; Barrow and Tipler, 1986, p. 22)

The root of Wheeler's frail reed taps into the quantum measurement problem. On the solution proposed first by London and Bauer (1939) the conscious observer plays an essential role in the transition from potentially to actuality; or, in the terminology we have been using, the reduction of a superposition to an eigenstate of the observable being measured (Process 1) is accomplished by means of registration on the consciousness of the observer. Here let it be noted that anthropic theorists are not above some double dealing. We have seen that they appeal to the Everett many-worlds interpretation of QM to generate an actual ensemble of worlds; but recall that the main motivation for this interpretation was to avoid Process 1 changes altogether, whether such changes are induced by conscious observers or otherwise. This fact is conveniently ignored when it does not suit. Secondly, even if one opts for a dualistic Process 1-Process 2 interpretation of QM, with conscious observers playing a central role in the former, it does not follow that without conscious observers the world would not have being, existence, reality, or actuality, but only that certain kinds of changes would not take place in it. After a Process 1 change the world is no more real or actual than before; and the QM state after measurement contains just as many (though different) unactualized possibilities as before.

Failing to find any firm ground in physics for PAP, the anthropic theorist can turn to the history of philosophy and find more fertile ground. But such is not my concern here. My concern is with attempts to wrap PAP in the cloak of scientific respectability. These attempts amount to no more than hand waving. As a scientific principle, the Participatory Anthropic Principle has a peculiarly apt acronym.

Finally, the Final Anthropic Principle states:

> (FAP) Intelligent information-processing must come into existence in the universe, and, once it comes into existence, it will never die out. (Barrow and Tipler 1986, p. 23)

What distinguishes FAP from other APs is that it lends itself to empirically testable predictions. For instance, Barrow and Tipler (1986, Ch. 10) show how their version of FAP restricts the mass spectra of elementary particles. The proponents of FAP appear to have put themselves in a no-win situation. Negative experimental results would refute FAP while positive results would only confirm the hypothesis that the universe is in fact such that life will never die out, not the stronger FAP hypothesis that the universe must be such that life will never die out. The move from "is" to "must" is supported by the SAP-PAP assumption that life must come into existence and the remark that if life dies out "long before it has had any measurable non-quantum influence on the Universe in the large, it is hard to see why it *must* have come into existence in the first place" (Barrow and Tipler 1986, p. 23). I leave it to the reader to evaluate the strength of the support.

4. Anthropic Explanations

The current widespread interest in anthropic reasoning is no doubt due largely to intimations that (in Dyson's words) the mind plays an essential role in the functioning of the universe. And yet when these intimations are followed up, all that one finds are empty teases or else unbridled and muddled speculation. PAP and FAP are good examples of the latter. An example of an empty tease is the suggestion that various features of the universe are consequences of our existence. Collins and Hawking (1973) are sometimes cited in this regard since they propose that the answer to the question "Why is the universe isotropic?" is "Because we are here." And yet a careful reading of their paper reveals that they are not asserting that isotropy is a consequence of life in either a causal or teleological sense.

Some popular presentations make it seem that what Collins and Hawking and other anthropic theorizers are endorsing is a milder principle which, with equal justice, can be characterized either as a principle of explanation or as a principle of anti-explanation. The former can be glossed as follows: Explanation consists in the reduction of puzzlement or surprise; and one's initial surprise at finding that the cosmos has feature *F* can be assuaged by noting that *F* is necessary for life as we know it. The latter can be glossed as: No explanation of feature *F* is called for; *F* should not be seen as puzzling or surprising since *F* is necessary for life. On either reading, the principle involves an obvious ambiguity which can be brought out with the help of the story of Harry. Harry's car skidded on wet pavement, jumped a guard rail, and started to plunge over the edge of a cliff towards the rocks 100 feet below. Harry awoke between clean sheets to find to his amazement that there were no broken bones. There is, of course, one rather uninteresting sense in which Harry should not be surprised; namely, he shouldn't be surprised that he is *observing* that his body is not a mangled mess since if it were he would be unable to observe it. (Compare to Collins and Hawking: "The existence of galaxies would seem to be a necessary precondition of any form of intelligent life. Thus there will be life only in those universes which tend towards isotropy at large times. The fact that have *observed* the universe to be isotropic is therefore only a consequence of our existence." (1973, p. 319; emphasis added)) On the other hand, Harry has every right to be surprised and puzzled by the *fact* that his body is not a mangled mess. Similarly, those physicists and philosophers who profess amazement at how "finely tuned" the laws of nature are in favor of life are hardly going to be satisfied by a demonstration that the confinement of the values of fundamental constants to narrow ranges about their actual values is necessary for life as we know it; indeed, that demonstration is precisely the source of their puzzlement.

Collins and Hawking and other responsible anthropic theorizers are not guilty of a crude fallacy. They are quite clear that puzzlement over a feature *F* is not to be reduced simply by demonstrating the necessity of *F* for life but by a coupling of such a demonstration with the idea of an ensemble of universes (see Collins and Hawking 1973, p. 319). John Leslie has taken anthropic theorizing a step further in arguing that the existence of the many features that make the universe hospitable to life is evidence either for Design or for a worlds-within-worlds model for the actual universe.

The litany of the many ways the universe is fine tuned for life falls into two parts. First, for example, a tiny change in the strong nuclear force would mean the absence of complex chemical elements needed for life (see Rosental 1980 for other examples). Second, for example, a change in the energy density at Planck time by an amount as small as 1 in 10^{-55} as compared with the critical density (corresponding to a flat universe) would mean either that the universe would have been closed and would have recollapsed millions of years ago or else that it would have been open with a presently negligible energy density. The second category does not call for an attitude of agog wonder-at-it-all. Rather, it points to a potential defect, in the form of a lack of robustness of explanation, of the standard hot big bang scenario, a defect which the new inflationary scenario promises to overcome by showing how exponential expansion in the early universe can turn fairly arbitrary initial conditions into the presently observed state (see Gibbons and Hawking 1982 and Guth and Steinhardt 1984). Nor is it evident that puzzlement is the appropriate reaction to the first category. A mild form a satire may be the appropriate antidote. Imagine, if you will, the wonderment of a species of mud worms who discover that if the constant of thermometric conductivity of mud were different by a small percentage they would not be able to survive.

Even if puzzlement as to the fine tuning of constants is appropriate, it does not follow that we must look for enlightenment either to Design or to worlds-within-worlds. Perhaps the answer lies in a deeper scientific theory which allows the values of fundamental constants to be computed from first principles. But even if this possibility is discounted and Design ignored, it still does not follow that we have reason to believe that our universe has a worlds-within-worlds structure with different mini-worlds having different values of the fundamental "constants." Inference to the best explanation, even if it is accepted as a valid principle of inductive inference, is of no help in the present context. Here "explain" means to remove a presumption of the puzzlement; but "I am puzzled by *P*, my puzzlement rests on presumption *Q*, therefore (probably) *Q* is false" is not a very appealing rule of inference.[5] In general, all that is warranted is the innocuous conclusion that it is advisable to investigate the presumption *Q*.

Is there any independent scientific justification for postulating a worlds-within-worlds structure for our universe? Anthropic theorizers are eager to seize upon any evidence that could conceivably motivate a positive answer. With one possible exception, I believe that they are grasping for straws. In Sec. 2 I have already given my reasons for skepticism about the appeal either to the Everett many-worlds interpretation of QM or to the idea that big bang universes run through multiple 'cycles.' Ellis (1979) describes a worlds-within-worlds scenario that can be coherently realized within classical general relativity theory. Ellis' imagined universe is infinite and chaotic, containing a myriad of regions in different states of expansion and contraction and possessing different degrees of homogeneity and isotropy. But Ellis offers no independent warrant for thinking that such a structure corresponds to the actual universe; indeed, the model was constructed specifically so as to lay the ground work for an anthropic "explanation" of the actually observed homogeneity and isotropy. Moreover, Ellis' model cannot be used as a basis for anthropic "explanations" of the values of physical constants since there is no plausible way in standard general relativity to patch together different regions with, say, different values of the gravitational coupling constant. And finally, Ellis' model illustrates a potential snag that applies quite generally to the anthropic approach. Grant that Ellis' model is chaotic in the sense that its mini-worlds represent a random sample from $\mathcal{W}$ (the set of big bang models—see Sec. 2 above). Then since the model is infinite, any feature such that $\mu\ (\mathcal{F}) \neq 0$ will be realized infinitely often (Ellis and Brundit 1979). But if the feature in question is unusual with a vengeance—measure zero—then the probability that it will be exhibited in some mini-world in the Ellis model is zero, and so no selection effect principle will suffice to explain away our puzzlement at encountering such a feature.

Linde's (1984, Secs. 10-11) version of the new inflationary scenario appears to hold out the best hope for anthropic theorizers. Linde imagines that the scalar Higgs field that leads to symmetry breaking in grand unified theories (GUTs) of elementary particles is chaotically distributed at the big bang and that as a result the universe contains many mini-universes, each of a size greater than the presently observable universe, with different mini-universes containing different properties of elementary particles, different number of observable spatial dimensions, etc. *If* the future course of science provides convincing independent evidence for GUTs and for Linde's speculative application of GUTs to cosmology, then the anthropic theorizers would have the kind of playing field they desire. But I caution that at present Linde's speculations are speculations. And I would emphasize again that outside of such speculations there are no general methodological or substantive reasons for positing the kind of many worlds structure needed to take anthropic reasoning beyond the very circumscribed application it had for Dicke.

5. Conclusion

Insofar as the various anthropic principles are directed at the evidentiary evaluation of cosmological theories they are usually interpretable in terms of wholly sensible ideas, but the ideas embody nothing new, being corollaries of any adequate account of confirmation. And insofar as anthropic principles are directed at promoting Man or Consciousness to a starring role in the functioning of the universe, they fail; for either the promotion turns out to be an empty tease or else it rests on woolly and ill-founded speculations. There remains the potentially legitimate use of anthropic reasoning to alleviate the state of puzzlement into which some people have managed to work themselves over various features of the observable portion of our universe. The alleviation takes place by extending Dicke's selection effect notion, as originally applied to temporal stages of a standard big bang model, to spatio-temporal stages of a worlds-within-worlds model. But to be legitimate, the anthropic reasoning must be backed by substantive reasons for believing in the required worlds-within-worlds structure. Assertions by anthropic theorizers to the effect that modern science provides many such reasons should be taken with a large dose of salt. Neither classical general relativity theory nor quantum mechanics provide any firm grounds for taking worlds-within-worlds models seriously, and while various speculative versions of the new inflationary cosmology may eventually provide such grounds, the verdict is at present very much in doubt.[6]

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NOTES

1. Some of the more important scientific papers are Barrow (1983), Barrow and Tipler (1978), Carr and Rees (1979), Carter (1974, 1976, 1983), Collins and Hawking (1973), Dicke (1961), and Tipler (1982). Philosophical assessments are to be found in Gale (1986) and Leslie (1982, 1983a, 1983b, 1985, 1986a, 1986b, 1986c). Popular accounts are found in Carr and Rothman (1985), Davies (1982, 1983), Finkbeiner (1984), Gale (1981), and Guillen (1984). A comprehensive survey and a very extensive bibliography are to be found in Barrow and Tipler (1986).

2. Note, however, that anthropic theorists try to turn the high probability of life against a steady state model of the actual universe. Tipler (1982) argues that if we were in a steady state universe we should be overrun by alien life.

3. Anthropic 'explanations' are discussed below in Sec. 4. Carter makes the Bayesian interpretation of WAP explicit in his (1983).

4. Explanation, construed as the reduction of puzzlement, may hinge on consciousness; see Sec. 4 below.

5. Perhaps it might be thought that the inference to worlds-within-worlds is more plausible if the puzzlement is framed in terms of the improbability of P, at least if the improbability is given an objective propensity or frequency interpretation. But in the cases at issue I don't see how, short of something like a Cosmic Dart Board scenario (see Sec. 1 above) such an interpretation is to be supplied. And even if it is supplied I don't see that an improbable outcome for a chance experiment gives warrant to think that this particular experiment has been run many times or that multiple copies of the experiment exist. Leslie (1986b) disassociates himself from this move which Ian Hacking has dubbed the "Inverse Gambler's Fallacy."

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