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MULTIPLE UNIVERSES AND OBSERVATION SELECTION EFFECTS

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The fine-tuning argument can be used to support the Many Universe hypothesis. The Inverse Gambler's Fallacy objection seeks to undercut the support for the Many Universe hypothesis. The objection is that although the evidence that there is life *somewhere* confirms Many Universes, the specific evidence that there is life in *this* universe does not. I will argue that the Inverse Gambler's Fallacy is not committed by the fine-tuning argument. The key issue is the procedure by which the universe with life is selected for observation. Once we take account of the procedure, we find that the support for the Many Universe hypothesis remains.[1]

Selection Effects

Whenever a sample is drawn from a population, some particular method must be used. Eddington's (1939) classic example involves fishing with a net. If we catch a sample of fish from a lake, and all the fish in the sample are bigger than six inches, this appears to confirm the hypothesis that all the fish in the lake are bigger than six inches. But if we then find out that the net used cannot catch anything smaller than six inches due to the size of its holes, the hypothesis is no longer confirmed. Or, at least, not as much. So the inference depends on the method of obtaining the sample. Call the method by which the sample was selected the *selection procedure*. There are an indefinite number of selection procedures, but there are only two that we will need.

A *random procedure* is one where each member of the population has an equal chance of being selected for the sample. In Eddington's example, this would be a case where each fish in the lake has an equal chance of being caught.

A *biased procedure* is one where only members with a certain property are selected for the sample. (This is a precisification of our ordinary language term "biased." It corresponds better to "maximally biased.") In Eddington's example the selection procedure is biased (in my new technical sense) toward the property of being more than six inches.

Let's consider a simple thought-experiment that models the selection effects of the fine-tuning argument. Suppose an urn contains either one ball or two, depending on the result of a fair coin toss (two if Tails, one if Heads). Each ball that goes in the urn will be either big or small. Which it will be depends on the result of another fair coin toss.

A sample of one is taken. It turns out to be small.
E = A small ball is selected.
Does E confirm Tails?

	Ball 1	Ball 2
Heads	Big or small	—
Tails	Big or small	Big or small

It depends on the procedure by which the ball has been selected. Consider two procedures for how a ball might be selected for a sample. First, a small hole might be opened, allowing one of the small balls out of the urn and into the sample. This procedure is biased toward the property of being small. Second, a large hole might be opened that allows any of the balls out of the urn and into the sample. This procedure is random. Let's work through these two possibilities.

Biased Procedure

Assume first that a small hole is opened so that the procedure is biased toward smallness. Say that E confirms T iff P(T|E) > P(T) (Salmon 1975) and let

H = Heads
T = Tails
E = A small ball is selected.

As the procedure is biased, a small ball will be observed whenever a small ball exists (otherwise nothing will be observed). The probability that a small ball exists given Heads is 1/2 (recall that it depends on the toss of a fair coin). The probability that a small ball exists given Tails is 3/4, because there is a second ball that might be small. Tails is confirmed, as the evidence was more likely given Tails (3/4) than Heads (1/2). This result can be shown using Bayes' Theorem:

$$P(T|E) = \frac{P(T)P(E|T)}{P(E)}$$

$$= \frac{1/2 * 3/4}{5/8} = \frac{3}{5} > P(T) = 1/2$$

There is a useful heuristic: if the procedure is biased toward p, and an instantiation of p is successfully found, the evidence confirms hypotheses in which there is a large population (rather than a small one).[2]

Random Procedure

Now suppose a large hole is opened. Then, no matter how many balls there are, there is a probability of 1/2 of a small ball being observed, as each ball has a ½ chance of being small. So neither Heads nor Tails is confirmed.

When the procedure was biased, P(E|T) was ¾, as the extra ball increased the chance that a small ball would be in the urn. But now that a ball is selected at random, the extra ball makes it no more likely that a small ball will be observed. So P(E|T) = 1/2.

Again, this is shown by Bayes' Theorem:

$$P(T|E) = \frac{P(T)P(E|T)}{P(E)}$$

$$= \frac{1/2 * 1/2}{1/2} = \frac{1}{2} = P(T) = 1/2$$

The heuristic here is that if the procedure is random with respect to p, then finding an instantiation of p doesn't confirm any hypothesis regarding the size of the population.[3]

The relevance of the selection procedure is easy to miss because in both cases the evidence looks the same. In both cases the evidence can naturally be described as "A small ball is selected." But the process by which the ball is selected affects the inferences we can draw and our total evidence must include this.[4]

The two-stage procedure is at the heart of observation selection effects. First is the process by which the nature of the population is determined. Call this the *ontic* process. In the above case, the ontic process results in there being either one or two balls, of particular sizes, in the urn. Then there is the process by which we come to observe a particular ball. Call this the *epistemic* process. This point about needing a two-stage procedure is a general one, and is discussed in detail by Hutchison (1999). To take our total evidence into account, we need to conditionalize on "I have learned E by process p," as opposed to just "E." I will argue that when the selection procedure is included in the fine-tuning argument, support for the Many Universe hypothesis remains.

The Fine-Tuning Argument

If the fundamental constants of the universe had been much different from their actual values, life could not have existed. For example, if gravity had been a bit stronger, the universe would have collapsed in on itself moments after the big bang. If it had been a bit weaker, the universe would have flown apart so fast that molecules could never have been formed. The same holds for nearly all the other fundamental constants (see McMullin 1993). (The initial conditions are also vital. For ease of exposition, I will take "right constants" to include right initial conditions.) The existence of every living thing in the universe is balanced on a knife-edge.[5] Nevertheless, life exists.

Proponents of the fine-tuning argument claim that the existence of life requires an explanation.[6] One explanation is that there are many universes, and that these universes have fundamental constants with different values spread out across the parameter space. This is a hypothesis that has been independently suggested several times, from Misner, Thorne, and Wheeler's (1973) oscillating universes to Susskind's (2005) Landscape hypothesis.

Not all versions of these theories entail that the other universes have different constants spread out across the parameter space, but I am interested in the versions in which they do. This restriction might reduce the prior probability of the hypothesis, but that doesn't affect my argument, which is about whether the hypothesis is confirmed by the evidence.

How does the evidence that the universe has the right constants for life confirm the hypothesis that there are many universes? The argument is very intuitive. The more trials of some kind of event there are, the greater the probability of any given outcome occurring. For example, the probability that at least one double six is rolled given one throw of a die is 1/36. However, if the die is thrown again, the probability of at least one double six being rolled is higher (over 1/20 instead of 1/36). So the evidence that at least one double six has been rolled is more likely given that the die is thrown a second time. Thus, the evidence that a double six has been rolled confirms the hypothesis that the dice have been thrown a second time.[7]

Similar reasoning applies to universes. Consider the following two hypotheses:

> Many Universe Hypothesis (MV): There are many universes with different values of constants.
>
> Universe Hypothesis (UV): There is only one universe.

The analogy to the dice cases is straightforward. Replace the dice throws with universes, and replace the result of getting a double six on a throw with getting a universe with the right constants for life. The probability of there being life given only one universe is very small. But if there are enough universes, the probability that there exists one with the right constants for life becomes very high. Thus, the evidence that there is at least one universe with the right constants for life confirms the hypothesis that there are many universes. Let's formalize the argument.

Let the proposition that at least one universe has the right constants for life be E. Let the probability that any given universe has the right constants for life be b. Let UV mean there is one universe and MV mean there are two universes. Assume equal priors (nothing turns on their value):

$P(UV) = 1/2$
$P(MV) = 1/2$

We can calculate how much learning E disconfirms the Universe Hypothesis, UV.[8]

$$P(UV \mid E) = P(UV)P(E \mid UV)/$$
$$[P(UV)P(E \mid UV) + P(MV)(P(E \mid MV)]$$
$$= (1 / 2b)/[(1 / 2)b + (1/2)(1 – (1 – b)2)]$$
$$= 1/(3 – b)$$

As $b \to 1$, $P(UV|E) \to 1/2$
As $b \to 0$, $P(UV|E) \to 1/3$

If b = 1, the evidence E becomes certain. So UV is not confirmed and keeps its prior value of 1/2. As b falls, the degree of confirmation of MV goes up, until we reach maximal values of $P(UV|E) = 1/3$ and $P(MV|E) = 2/3$ as b approaches 0. This gets us to the conclusion of the fine-tuning argument, that E confirms MV.

Note that MV is only confirmed if the prior probability of E—that at least one universe has the right constants for life—is less than one. Sober (2003) contests this assumption on the grounds that we could not have discovered a universe with the wrong constants for life. Similarly, he thinks that if you survive a firing squad, you do not gain evidence that they intended to miss. Nor, according to Sober's position, do you gain evidence that the guns jammed, or that they contained blanks, or anything else that might explain your survival. This position strikes me as highly implausible. [9]

Analogies aside, I think Sober's objection is answered by Monton (2005), who assimilates the problem to the problem of old evidence (Glymour 1980). If we include everything we know at time t in the background evidence, then none of these facts known at time t can confirm anything according to standard Bayesian confirmation theory.[10] So "at least one universe has the right constants for life" can't confirm anything if it is already known when we start our Bayesian calculations. But it is generally acknowledged that Bayeisan confirmation theory gives us the wrong result in such cases, and must be modified to allow old evidence to confirm hypotheses. Monton applies the standard counterfactual solution (Howson 1991) to generate the result that the relevant prior probability that at least one universe has the right constants for life is less than 1.

Henceforth, I will assume that the prior probability that at least one universe has the right constants for life is less than 1. It is important to be clear about this assumption, which will be explicitly invoked in the section titled "White: The Converse Selection Effect."

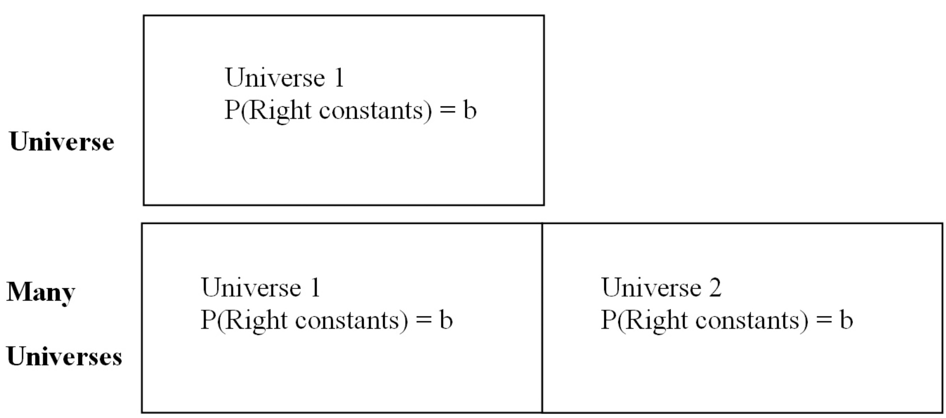

Figure 1: The Fine-tuning Argument

So for the duration of the paper, I ask that you suspend your belief that you exist, or that there is any universe that has the right constants for life, and consider the possibility that there isn't. It might be somewhat disconcerting to consider such a possibility, but I think it is a perfectly coherent modal thought, and the costs of dismissing it are high.

Hacking: The Inverse Gambler's Fallacy

Hacking's objection is that the fine-tuning argument commits a mistake he dubs the *inverse gambler's fallacy* (Hacking 1987). To explain this, we can start with the familiar *gambler's fallacy*.

> *Gambler's Fallacy*. To think that a certain outcome on a gambling device is more likely to occur on a particular trial after a series of earlier trials on which that outcome did not occur.

This fallacy is committed by someone who thinks that a run of non-double sixes increases the probability that the next roll will be a double six. The Inverse Gambler's Fallacy makes a similar mistake, but in the other direction.

> *Inverse Gambler's Fallacy*. To think that a certain outcome on a particular trial makes it more likely that other trials have taken place.

Hacking demonstrates this fallacy with the following example. This example, and the variants that follow, all have the same background:

> Background: A pair of dice are to be thrown either one time (U) or a million times (M); you don't know which, and you must assess whether you have learned evidence for either hypothesis.

> Case H (Hacking): You walk into the room just before a throw takes place, and you observe the outcome. A double six comes up.

In this case, M is not confirmed. Hacking correctly points out that someone who thinks M is confirmed would be committing the Inverse Gambler's Fallacy. But why is it a fallacy? Hacking's diagnosis of the mistake being made is that you have the specific evidence that *this* throw is a double six, and how things are on this throw is independent of how many other throws there might be. He claims that the general evidence that "at least one double six has been rolled" would confirm M, but the specific evidence that "this roll is a double six" doesn't confirm M.

Hacking then argues that the same applies in the cosmology case. Our total evidence is that *this* universe has the right constants for life, and how things are with this universe is independent of how many universes there might be. So finding that this universe has the right constants for life doesn't confirm Many Universes.

But I think Hacking has misdiagnosed the root of the Inverse Gambler's Fallacy. What matters is not the specificity of the evidence, as Hacking claims, but the *epistemic process* by which it was found. To see this, compare what happens when we change the process, as McGrath (1988) does in his variation (with the same background that a dice will be tossed either one or a million times):

> Case G (McGrath): You take a nap and instruct that you be woken only if a double six comes up. You are woken and observe a double six.

In this case M is confirmed by the evidence.[11] But this should be puzzling, as it looks like Hacking can make the same objection. We again have the specific evidence that *this* roll is a double six. Rigidly designate the roll you observe as Alpha_T. Your total evidence is that Alpha_T is a double six. Shouldn't this specific

Table 1

	Selection procedure is	M is confirmed?
Case H (Hacking)	Random	No

Table 2

	Selection procedure is	M is confirmed?
Case H (Hacking)	Random	No
Case G (McGrath)	Biased towards double six	Yes

evidence be independent of M? Doesn't focusing on the specific evidence show that the Inverse Gambler's Fallacy is still being committed, just as it was in Hacking's case H?

No. The difference is due to the fact that the process is now biased toward double sixes. Recall the heuristic: if the process is biased toward p, and an instantiation of p is successfully found, the evidence confirms hypotheses in which there is a large population rather than a small one. So observing a double six does confirm M. We'll go through this in detail in a moment.

The failure of confirmation in case H is not caused by the specificity of the evidence, but by the process by which the evidence was found. The evidence fails to confirm M because the throw was selected for observation by a process that was random with respect to double sixes. You walked into the room and were just as likely to observe a double six as any other outcome. The heuristic is that if the procedure is random with respect to p, then finding an instantiation of p doesn't confirm any hypothesis regarding the size of the population. So observing a double six doesn't confirm M.

Let's go through exactly why M is confirmed in G, using the two-stage procedure. First, the ontic stage ensures that $Alpha_T$ is more likely to exist if there are a million rolls. For example, $Alpha_T$ might be the 50th roll, which would only exist if there are a million throws. Or it might be the roll, if any, on which the dice rotated exactly 6.94851 times combined. This too is more likely to exist if there are a million rolls. Second, the epistemic stage ensures that $Alpha_T$ is more likely to be observed than other throws because $Alpha_T$ is a double six, and the biased procedure ensures that only double sixes are observed.

So we see that, contra Hacking, the specificity of the evidence is not the issue, but the process by which it is found. Specific evidence found by a biased process still confirms M. Similarly, general evidence (i.e., some double six is rolled) found by a random process does not confirm M.

We can apply this analysis to the cosmology case. Rigidly designate this universe as Alpha. Do the two conditions needed for confirmation of Many Universes hold? They do. First, does the Many Universe hypothesis make the existence of our universe, Alpha, more likely? Yes. A universe is Alpha in virtue of its properties. The more universes there are, the more likely that a universe with Alpha's properties, i.e., Alpha, exists.[12] (Recall we are considering versions of the Many Universe hypothesis according to which the different universes have different constants.)

Second, by what procedure has our universe, Alpha, been selected for observation? Alpha is more likely to be observed than other universes because Alpha has the right constants, and only universes with the right constants can be observed.[13] We have successfully found a universe with the right constants by a biased method, so we end up with confirmation of Many Universes. The fine-tuning argument survives Hacking's objection.

This completes my main argument.[14] In the next section I argue that White's (2000) development of Hacking's objection doesn't succeed on its own terms. Then, in the final section, I argue that even if it did succeed, it would be dialectically ineffective against the fine-tuning argument.

White: The Converse Selection Effect

White doesn't deny any part of the argument I give above, so we need to be clear about the dialectic. My argument relies on the premise that we could *only* have existed in a universe with the right constants for life.[15] White attacks the assumption that we could have existed in *any* old universe with the right constants for life, i.e., if some universe other than Alpha had the right constants for life, we could have existed in that universe. Although this assumption isn't technically necessary for the fine-tuning argument, I think it is true, and that it is the right way to think about fine-tuning. So I will defend this assumption in this section. Then I will show how the fine-tuning argument can be applied even if the assumption is denied.

So could we have existed in some universe other than Alpha that happened to have the right constants? White suggests that we could not have. He does not accept that McGrath's case G is analogous to our position with respect to cosmology, and suggests the following analogy instead:

> Case W (White): You and an unspecified number of sleepers have a unique partner who will roll two dice. Each sleeper will be woken if and only if *her* partner rolls a double six. You are woken and observe a double six.

You have no evidence that confirms M in case W. This is because the process in W is not biased toward double sixes, it is biased toward your roll being a double six. That is, the only thing you could observe is that your roll is a double six. So the possible existence of other rolls becomes independent of your being woken, and M is not confirmed.

White holds that to get confirmation of M, you must be more likely to be woken given that rolls other than $Alpha_T$ exist than if no roll other than $Alpha_T$ exists. White calls this the converse selection effect.

> Converse selection effect (Dice): If some roll other than $Alpha_T$ exists then you are more likely to be woken than if no roll other than $Alpha_T$ exists.

The same principle applies to the cosmology case:

> Converse selection effect (Cosmology): If some universe other than Alpha exists, then we are more likely to exist than if no universe other than Alpha exists.

White claims that there is no converse selection effect in the cosmology case. If some universe other than Alpha existed, would it mean you were more likely to exist than if it didn't?

It seems to me that you would be more likely to exist. Keep in mind that we cannot assume as background knowledge that there is any universe with the right constants for life or that you exist at all. (Recall the earlier discussion of Sober.) So let's ask: what would be required for you to exist? Presumably certain features of the universe would have to be arranged in a very specific way. For example, we might need a planet with water, a race of creatures with a certain history and culture, and so forth. Surely such conditions could have been satisfied in a different universe. Or perhaps instead my existence requires the actual matter of which my brain consists,

Table 3

	Selection procedure is	**M is confirmed?**
Case H (Hacking)	Random	No
Case G (McGrath)	Biased towards double six	Yes
Case W (White)	Biased towards your roll being double six	No

or perhaps my existence requires the instantiation of some simple irreducible property. Couldn't any of these conditions have been satisfied in a different universe? For any given universe the probability that such conditions be satisfied is small. But nevertheless, for each universe that exists, the probability that the relevant condition is satisfied goes up, so the probability that you exist goes up.

White disagrees. His discussion is very compressed, but I can find two arguments. The main argument seems to be the following:

> We have no reason to suppose that we would exist if a different universe had been fine-tuned. In order for the Multiple Universe hypothesis to render our existence more probable, there must be some mechanism analogous to that in [case G] linking the multiplicity of universes with our existence. But there is no such mechanism. (White 2000, p.269)

The idea seems to be that we have no reason to think we would exist in a different universe, because there is no mechanism connecting that other universe with our existence. It is unclear to me exactly what White means by "mechanism" and what he demands of it. (He doesn't use the word anywhere else in the paper.) It's true that we don't have the same kind of mechanism as we do in case G, i.e., someone deliberately influencing what you can observe. But we surely don't need anything like that to get confirmation. We don't need a particular *reason* to think we would exist in a different universe, we just need the possibility that we could have.

This leads us to White's second argument—that we *could not* have existed in a different universe. Why think we couldn't have existed in a different universe? One could use Kripke's (1980) necessity of origins thesis to claim that it is metaphysically impossible for us to have existed in any other universe. But necessity of origins with respect to universes is implausible, and White does not endorse it. (Even if I could not have been produced by any other parents, why couldn't my parents, and theirs . . . have existed in a different universe? See Manson and Thrush 2003 for this response.) So what arguments does White give for denying that we could have existed in a different universe?

He points out that a particular qualitative state cannot be *sufficient* for our existence. This is because there might be two universes in the same qualitative state, and we cannot exist in both.[16] I agree, but this is not to the point. We don't need to claim that a qualitative state of a universe is sufficient for our existence. We just need to claim that the conditions that are sufficient for our existence might be instantiated in universes other than Alpha.

White's point would be relevant if it was taken as given that we exist in Alpha. Then, of course, we couldn't exist in any other universe. But we cannot assume we exist at all, let alone that we exist in Alpha.

The same point holds in case G (where you are woken if a double six is rolled). Stipulate that you are to be woken no more than once. *Given* that you are woken on roll $Alpha_T$, there is no possibility that you are woken on any other roll. But being woken on roll $Alpha_T$ is not something we should hold fixed when assessing the counterfactual "I could have been woken on a different roll."

White has given no convincing argument that we couldn't have existed in another universe, and it seems plausible to me that we could have. If so, the converse selection effect holds and the Many Universe hypothesis is confirmed by the evidence of a universe with the right constants.

Why the Fine-tuning Argument Works Even If There Is No Converse Selection Effect

It turns out that a converse selection effect is not needed for the evidence to confirm Many Universes. All we need is for the selection procedure to be biased. Let's assume necessity of origins with respect to universes; then we could only exist in *this* universe, Alpha. Instead of the process being biased toward finding the property of [being a universe with the right constants for life], the process is biased toward finding the property of being Alpha. Whereas before, the selection procedure resulted in us observing some universe with the right constants for life (or observing nothing), now the selection procedure results in our observing Alpha (or observing nothing). It turns out that if we successfully observe Alpha, we have confirmation for the Many Universe hypothesis. We just run through the fine-tuning argument, substituting "Alpha" for "a universe with the right constants for life."

Recall the two-stage procedure. The first stage is that if there are Many Universes, there is a greater chance that Alpha will exist (same as before). At the second stage, necessity of origins tells us that we could only observe Alpha. So the process is biased toward the property of being Alpha. A property has been successfully found by a biased procedure, so observing Alpha confirms Many Universes.

In fact we get a *bigger* shift than before if we assume necessity of origins. Previously, we could have existed in any universe with the right constants for life. We weren't picky. On the assumption of necessity of origins, we are maximally picky. There is only one universe in which we could possibly exist. If that universe doesn't exist, we don't exist. If we find, lo and behold, that our universe does exists, then Many Universes is strongly confirmed.

Extending the notation from earlier, let b represent the probability that a given universe has the property the procedure is biased toward. We saw that the degree of confirmation of Many Universes rises as b falls. Given necessity of origins, b is the property of being Alpha. Assuming that the probability that [a given universe is Alpha] is smaller than the probability that [a given universe has the right constants for life], necessity of origins results in greater confirmation for Many Universes.

Let's give one final dice case to model this.

> Case N (for necessity): Suppose you know you are one of a million people who is paired with a million *possible* dice rolls. If the dice are rolled once (U), then only the individual paired with that roll is taken to the lab, allowed to take a nap, and woken if his roll is a double six. If the dice are rolled a million times (M), all one million people are taken to the lab and allowed to take a nap, and each is woken if his roll is a double six. You find yourself taken to the lab, you take a nap, and you are woken to observe a double six.

Table 4

	Selection procedure is	**M is confirmed?**
Case H (Hacking)	Random	No
Case G (McGrath)	Biased towards double six	Yes
Case W (White)	Biased towards your roll being double six	No
Case N (Necessity)	Biased towards your possible roll being double six	Yes

Is M confirmed? Yes. It is not confirmed by the fact that your throw is a double six. It is confirmed by the fact that you have been taken to the lab in the first place. Similarly, given necessity of origins, Many Universes is not confirmed by the fact that Alpha has the right constants for life, but by the fact that Alpha exists at all,[17] together with the procedure by which that fact was discovered.

Conclusion

The procedure by which a piece of evidence came to be learned is always relevant to the conclusions we can draw. The Inverse Gambler's Fallacy objection rightly draws our attention to the procedure by which our universe was observed. I have argued that when the procedure is taken into account, the fine-tuned nature of the universe confirms the Many Universe hypothesis.[18]

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NOTES

1. The main contenders to explain fine-tuning are Many Universes and Intelligent Design. To the extent that my argument supports Many Universes, it undercuts the argument for Intelligent Design.

2. Two caveats. First, we must assume at least (a) that the size of the population is independent of the distribution of objects, and (b) that p might not have been instantiated. These will hold in all our cases. Second, there are some selection procedures that satisfy our definition of bias, but for which the heuristic doesn't hold; for example, the procedure that selects a single object at random, and reports nothing if that object doesn't have the desired property. But this will be ignored as it is implausible that our observation of this universe could be modeled by such a strange procedure.

3. Again assuming, at least, that the size is independent of the distribution of properties and that p is not certain to be instantiated. If p is certain to be instantiated, the small hypothesis is confirmed.

4. I have left open whether knowledge about the process should be included in background knowledge or new evidence. This may vary from one agent to another, but won't affect the final result of the update, as learning E1 followed by E2 is equivalent to learning E1 & E2.

5. I have found that some philosophers are hostile to this claim for reasons I find puzzling; physicists seem to take the claim as data. See Colyvan et al. (2005) for a technical argument that it is not improbable that the universe be fine-tuned, and Monton's (2005) response.

6. These proponents include Craig (1988), Leslie (1989), Swinburne (1990), van Inwagen (1993), Manson (1998), and Parfit (1998). Sober (2003) objects that no such explanation is needed. I will discuss his objection at the end of the section.

7. The procedure in this case is biased toward double sixes. This is the default assumption in such examples involving conditional probability, which is how I could explain the case without mentioning procedures; it is generally assumed that if E is true, E is discovered. The procedure is also biased in the cosmology case that follows; that the procedure is biased is the key premise of this paper's argument. Note that randomness is the default assumption in statistics. I suspect this interesting divergence, which I have never seen commented on, is largely responsible for the current disagreement. See Hutchison (1999) for a detailed discussion of bias as related to conditional probability.

8. These calculations are structurally identical to those in the Generalized Sleeping Beauty problem (White 2006). I develop the close connection between these and other self-location problems elsewhere.

9. Sober has recently changed his mind. See Sober (Forthcoming).

10. This is because P(H|E) = P(H) if P(E)=1.

11. If the dice are thrown once, the probability you are woken is 1/6. If the dice are thrown a million times, the probability you are woken is 1–(5/6)^1000000, which according to my calculator is 1.

12. Could one deny that more universes make Alpha more likely to exist? One could argue that Alpha necessarily exists, or that if any universes exist, then Alpha does. I don't think such a position would be plausible.

13. What if we could have existed in a universe with the wrong constants due to some freak coincidence? Many Universes would still be confirmed by our existence. All we need is that we are *more likely* to observe a universe with the right constants than with the wrong constants. I have defined "bias" along the lines of maximal bias as it makes things clearer. But a more mildly biased procedure that successfully finds the property that the bias is toward would also confirm a Many Objects hypothesis.

14. Bostrom (2002), Juhl (2005), and Oppy (2006) all have discussions of the Inverse Gamber's Fallacy that are similar to mine in certain ways, but none of them are explicit about how selection effects work.

15. Again, strictly speaking all I need is that we are more likely to exist in a universe with the right constants for life.

16. "It is certainly not sufficient for us to exist in some universe, Beta, that Beta is fine-tuned, or even that Beta is qualitatively exactly as Alpha actually is. After all, if we postulate enough universes, the chances are that there exist several life-permitting universes, perhaps even universes with precisely the same initial conditions and fundamental constants as our universe, and containing human beings indistinguishable from us. But *we* do not inhabit those universes, other folks do" (White 2000, p. 268; italics in original).

17. This is why the right constants sometimes seem to drop out of the fine-tuning argument. See White's postscript in Manson (2003).

18. I would like to thank the UBC Probability Reading Group, Branden Fitelson, Josh Snyder, Elliott Sober, Mike Titelbaum, an anonymous *American Philosophical Quarterly* reviewer, and audiences at the 2004 Formal Epistemology Workshop at the University of Texas, Austin; the Stanford-Berkeley Graduate Conference 2004; and the Stanford Graduate Student Workshop 2003 for helpful comments and discussion on earlier drafts of this paper.

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