CAN SCIENCE SHAVE GOD?
THE MULTIPLY LIMITED VALIDITY OF
OCKHAM'S RAZOR

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Abstract

I argue that Ockham's razor is only one of at least 34 factors to be weighed in scientific theory formulation or assessment, with no principled way of doing any weighings. And that is the sense in which I claim that Ockham's razor is of multiply limited validity. The function of the razor is not ontological. For there are just as many entities as there are. Nor is its function epistemic. For it is used to decide between empirically equivalent theories. Thus its function can only be pragmatic. And that gives it a normative aspect. For it has pragmatic value. All of the factors, including the razor, logically can conflict with and limit each other, both singly and in combinations. And there is no principled way to decide any such conflicts. Thus we cannot use the razor simply to 'bean count' the entities of the 'best' theory, as so many writers do. This includes scientific theories, going back at least to Laplace, that use the razor to shave God as an unnecessary hypothesis. In fact, Albert Einstein and some of the great Quantum physicists find that religion adds an extra dimension of ontological understanding of the world. And that weighs in favour of keeping God. Indeed, the existence of the very issue whether there is such an extra dimension of understanding implies that God cannot simply be 'bean counted' out of the picture by scientists using the razor. For all the dimensions of understanding need to be weighed and balanced to the extent possible, and this dimension is not even scientific. But in the present paper, I mainly discuss the role of the razor in scientific theories, so as to provide an independent theory of the razor that is separate from the religious question.

Keywords: Ockham's razor, God, science, Willard Van Orman Quine, Albert Einstein

1. Introduction

  William of Ockham's famous razor is very widely used in Science and philosophy, and rightly so. Many state it as 'Entia non sunt multiplicanda praeter necessitatem', or 'Do not multiply entities beyond necessity'. Some explain it as meaning, 'Do not admit entities there is no need to admit, in order to describe or explain something'. But many simply refer to it without even quoting it. And

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almost no one actually examines it. Most simply accept it and apply it automatically without any further ado, as if 'bean counting' entities were a mechanical decision procedure, and there were no other factors to consider. Some qualify it with 'caeteris paribus', or 'other things being equal'. But while that general 'blanket' qualification is a great improvement, it is not an examination of what other factors might be considered.

The task of this paper is to provide a critical examination of the razor, both in itself and in light of all the other factors that must be considered in theory assessment. This is basic not only for Science, but also for the two main modern philosophical traditions. For the razor is the heart of deconstruction in Continental philosophy, and is the heart of eliminative logical analysis in the Anglo-American analytic tradition. And that makes it even more puzzling why so few actually examine it.

We should note at the outset that the razor is an imperative sentence, not an indicative one. It is not a true or false statement. It is advice. And by the term 'validity' in the paper's title, I mean its advisable scope. Granted, 'It is advisable to use the razor' is a true or false statement. But it is true if and only if the razor is good advice.

In all metaphysical questions, the 1914-1918 Russell seeks the least number of entities through his eliminative interpretation of logical analysis, expressly citing Ockham; see especially Russell [1]. Quine eliminates the very difference between Philosophy and Science through his all-encompassing naturalism [2], and then applies Ockham's razor, as well as his more general program of simplicity of which the razor is part, to all theory, so as to eliminate as many entities as he can. And in Philosophy of religion, what could be more famous than Laplace's reputed remark to Napoleon? When asked why God did not appear in his *Celestial Mechanics*, Lapace replied, 'Sire, I had no need of that hypothesis'. As Stephen Hawking points out, Laplace might not have been denying that God exists, but only denying that God was needed to explain astronomy [3]. But either way, the validity of the razor is of vital concern to the interface of Science and religion.

While Ockham's razor is very helpful in Science, and often indispensable as a practical matter, it is not the last word on what there is, either in Philosophy or in Science.

At least three questions arise. (1) What is the proper role or function of the razor, or does it have more than one? (2) Are there limits to its advisability or helpfulness? (3) Is it or should it be the sole factor by which we decide how many entities to admit? My answers to these questions are respectively: (1) merely pragmatic, (2) yes, at least 33 other factors limit it, and (3) therefore no, clearly not. I shall discuss these three questions in order.

2. Is the razor ontological, epistemic, pragmatic, normative or heuristic?

The razor's proper function is merely pragmatic. This seems obvious on the face of it. But for those who do not already find it obvious, I shall now argue

for that.

The razor's function is not ontological in any direct or straightforward sense. For the job of Ontology (really Metaphysics) is to describe 'the metaphysical furniture of the world'. Thus it ought to describe exactly as many entities as there are. And the simplest theory is not logically guaranteed to do that. In fact, the simplest theory is often wrong. Things are often more complicated than we think. Thus the concepts of simplest theory and of how many things actually exist are not only different, but are logically unrelated. Thus the razor logically cannot simply decide or determine what there is. The most it can do is provide limited guidance on what ontological commitments a theory should make.

Nor is the razor's function epistemic. For we use it to help decide between empirically equivalent theories. And there evidence logically cannot be the deciding issue by definition. Thus the concepts of simplicity and of evidence are not only different, but are logically unrelated.

Thus, if the only three options are that the razor's role is ontological (metaphysical), epistemic, or pragmatic, then its function is pragmatic. Any mix and match combinations of pragmatism with the other two options are ruled out by the arguments I just gave.

The razor is often said to be heuristic in function [4]. But that depends partly on what is meant by 'heuristic', and partly on whether the razor is actually helpful for a given theory. If it is heuristic if and only if it is helpful, this does not advance the analysis. We may say that the razor is not individually heuristic in the sense that it cannot predict or discover, or in that sense explain anything by itself. But it is holistically heuristic in that it is one factor in the overall scientific procedure of assessing theories that can and do predict, discover, and explain things, including whether certain entities are there.

Can we say that the razor is pragmatic *as opposed to* normative (evaluative)? Or can we conversely say that the function of the razor is normative *as opposed to* pragmatic? On the face of it, there are many norms that are not pragmatic. Ethics is full of them. But there is no such thing as being pragmatic but not normative. *Norms* are opposed not to *pragmatic norms*, which are in fact a species of that genus, but to *descriptions*. Recall Hume [5] on the impossibility of deriving 'ought' from 'is', or value from fact. And recall Mill's famous book *Utilitarianism*. It implies that all and only *desired* factors are *desirable* [6]. And as such, they are norms. And deciding how to weigh rival factors is a pragmatic evaluation too. In fact, is not pragmatism just utility?

Are not pragmatism and prudence distinct only in reason? And is not prudence a virtue? How then can pragmatism fail to be a value or a norm? And what about the Roman general Publius Gaius Cornelius Tacitus, who said, 'Discretion (prudence, pragmatism) is the *better* part of valour?' Prudential ethics belongs to Ethics. And while pragmatically looking out for number one is egoistic (egoism belongs to ethics too), the pragmatic factors in scientific theory assessment are, as a general rule, of public value to everyone. For as a general rule, a simpler theory is simpler for everyone.

To say that the razor or any of the other factors in theory assessment is pragmatically helpful, convenient, useful, or of utility, *is* to say they have pragmatic value. Every single factor is a caeteris paribus norm: 'Other things being equal, a theory *ought* to admit as few entities as necessary'. 'Other things being equal, a theory *ought* to be consistent with as much existing theory as possible'. And to say that the factors can pragmatically outweigh each other is to say that in pragmatic ethics, they can *normatively*, that is, *ethically*, defease each other.

Quine and Ullian expressly call simplicity, and all of their other factors in theory assessment, whether they are pragmatic or not, 'virtues' [7]. And all virtues are normative.

If two scientific theories are empirically equivalent, that is, predict and retrodict things equally well, then they are of equal epistemic value. Then other things being equal, we should pick the theory that admits fewer entities as a purely practical convenience. But Quine claims that simplicity is *itself* a kind of evidence. Quine says, "Insofar, simplicity itself - in some sense of this difficult term - counts as a kind of evidence; and scientists have indeed long tended to look upon the simpler of two hypotheses as not merely the more likable, but the more likely" [8]. And that claim would include Ockham's razor as a basic part of Quine's general program of simplicity. Quine can even invert my argument and say that if one of two *empirically* equivalent theories is simpler than the other, then the two theories are not *epistemically* equivalent, nor even *holophrastically* empirically equivalent, since the very simplicity of the simpler theory is 'holophrastic' empirical evidence for the simpler theory.

The problem is that Quine gives us no reason to believe his claim that simplicity is itself a kind of evidence. It is even simpler not to make the claim! All he does is commit the logical fallacy of appeal to the authority of scientists - and *they* have no empirical evidence for the claim either. How could they? How could it even be logically possible for empirical evidence to confirm or disconfirm in the slightest whether simplicity is a kind of evidence? And since my view is prima facie correct, the burden of proof, not to say the burden of producing even the slightest evidence for his claim, is on him to show otherwise. But instead of doing that, he simply *assumes* that scientists, qua scientists, are right to feel that the simpler hypothesis, as such, is more likely. Thus we can add begging the question to the list of his logical fallacies here. In fact, it is simpler to assume that scientists, not being philosophers, are simply confusing simplicity with evidence - if they really feel this way at all.

On Quine's holism, all theory, including Logic and Mathematics, faces experience holistically. Thus he can offer any rational argument for his claim that simplicity is itself a kind of evidence, and then deem the argument 'holophrastically empirical'. And according to his claim, the simpler the argument for his claim, the better evidence for his claim it will be! But he never produces an argument. All he does is appeal to the feeling of scientists. He does not even try to show that it really is their feeling. In fact, on his holism, my arguments *against* his claim are holophrastically empirical too! And theory

includes epistemology. Thus for Quine, all evidence is holistic. Thus he rejects any 'given' foundational epistemic data, which is absurd on the face of it. On pain of vicious regress of data, some data must be given.

Perhaps we could dress up Quine's holistic theory of evidence as a holistic theory of *truth* that applies to *statements* that this or that is evidence, or even as a holistic theory of *meaning* which applies to the *term* 'evidence'. But that only postpones the problem. Russell says, "Obviously there must be a limit to this [holistic] process, or else all the things in the world will merely be each other's washing" [9]. And that is just the same vicious regress argument I was describing. It applies to truths and meanings - including epistemic truths and meanings - just as well as it applies to epistemic data. And there are individual truths, meanings, and epistemic data on the face of it.

In fact, Quine's claim that simplicity is a kind of evidence is not scientific at all. It is a matter not for Science, but for Philosophy. For it is logically impossible for empirical evidence to count for or against it. What scientific experiment could we possibly perform? Can we look through a telescope and see that simplicity is a kind of evidence? There is not even a sound rational argument for the claim that Quine can deem to be 'holophrastically empirical'. At any rate, I cannot think of any, and he offers none. And if my earlier arguments are correct, then it is impossible to find any sound argument for the claim. For the razor has no epistemic function in the first place. It is merely pragmatic. And that comports with common sense. Who would ever think that simplicity is a kind of evidence, or has any epistemic value at all? The common sense view is quite the opposite. It is precisely that if even if two theories have equal epistemic support, one can be simpler than the other. And the reason seems obvious: simplicity in general, and the razor in particular, are simply too far from what we *mean* by evidence to count as kinds of evidence. They are not even *part* of what we mean by evidence. They are a different *kind* of thing. Thus Quine is pounding a square peg into a round hole. And our discussion multiply refutes his holism.

Perhaps Russell may succeed where Quine has failed. For Russell, the razor is pragmatic *because* it is epistemic in a negative and indirect sense. Thus he holds that the razor is negatively and indirectly epistemic. Russell's argument is that it is pragmatic *not* to accept entities that we do not *know* exist, and that our evidence-based theory does not *require* to exist. In this way, we avoid the mistake of *admitting* things that logically might *not* exist behind the impenetrable curtain of observational sense-data [1]. Russell's argument fails because it is equally pragmatic not to *reject* entities we do not know do *not* exist. In that way, we avoid the mistake of *rejecting* things that logically *might* exist behind the curtain of sense-data. Russell is actually discussing the ontological commitments of logical analyses, not of scientific theories; but the difference makes no logical difference.

To sum up, the function of the razor is neither ontological nor epistemic, but pragmatic. It logically can have no ontological function because simplicity and ontology are really and wholly distinct. They are not even distinct only in

reason. If the simplest theory happens to be the theory that truly describes which things exist, that is a logically contingent fact. From the logical point of view, it is a mere coincidence. In fact, the most complicated theory logically might be the one that truly describes which things exist. Likewise, the razor logically can have no epistemic function because simplicity and evidence are really and wholly distinct. They are not even distinct only in reason. If the simplest physical theory happens to be the theory that is best supported by the evidence, that is a logically contingent fact. From the logical point of view, it is a mere coincidence. In fact, the most complicated theory logically might be the one that is best supported by the evidence. My example of the elevator will make both of these points clear in a moment, if they are not clear already.

3. Are there any limits to the razor's helpfulness or advisability?

This was our second question. The answer is clearly yes. For in many perfectly ordinary cases, Ockham's razor clearly gives the wrong results. Suppose there are two empirically equivalent theories that predict equally well how an elevator behaves or works, but one gives a simpler description of its internal mechanism. The razor counsels us to pick the simpler theory. And we might give a very simple and effective explanation indeed of how an elevator works. But if we actually take the elevator apart and inspect the mechanism, we may find that it is more complicated than we thought, and that the more complex theory is the true one. While the evidence (the external behaviour of the elevator) is identical for both theories, the actual parts inside the elevator confirm the more complex theory, and disconfirm the simpler theory. Thus the example shows that simplicity and evidence are logically independent concepts. It also shows that the simplicity of the theory and the ontology of the elevator are logically independent.

One might object that the razor is correct for the *full* theory of the elevator, which would include *all* the evidence, including *both* its external behaviour and its internal mechanism. My reply is that Science has always been a work in progress. We have never had a full theory of *anything*, and the razor's function is to help us decide among the theories we actually have. If we had the true theory of *everything*, including all the evidence, both external and internal, we would be omniscient. If we attained the true theory of everything, we would know exactly how many entities there are, and we would no longer need the razor for any function at all - ontological, epistemic, *or* pragmatic. To vary the famous metaphor of Wittgenstein's *Tractatus*, the razor is like a ladder which we use to help climb up to the true theory, and can then discard, along with any the other ladders (factors) we used. And if the razor cannot help with the actual theories we have, like the two theories in the elevator example, then what good is it?

Let us now move beyond human artefacts like an elevator, which we can (within causal limits) deliberately design to be as simple or as complex as we please, with no telling from its external behaviour just how simple or complex it

is inside, and look instead at the proper domain of Natural science: Nature. Well, the razor often counsels wrong results here too, as the reader doubtless already knows.

On the level of living organisms, David Hume observed that Nature is profligate and wasteful, to say the least. And that is in fact Hume's [10, 11] main argument against the teleological argument for the existence of God, also called the argument from design. For organic nature shows a profligate and wasteful design, if it shows any design at all. I merely add that this includes internal organs. Even we humans have some half a dozen organs that we no longer need, and whose existence therefore cannot be predicted from our external behaviour. The process of natural selection over time, especially in a changing environment, often results in plants and animals that are far more complex than they need to be, with parts that no longer (or perhaps never did) play a significant role in their health, well-being, or survival, but that at least did not interfere with their survival.

Arthur Schopenhauer may be right that birds and fish are admirably designed to serve the functions they perform, and that this can only be explained by some sort of functionalism or even teleological based on the will to live [12-14]. I merely add that these very same birds and fish logically can be either simpler or more complex than they are, and serve the same functions just as well. Thus organic functionalism and simplicity are logically unrelated.

On the level of pure Physics, the case against the reliability of the razor is even worse. For our theories have never been complex enough. Stephen Hawking says, "A lot of prizes have been awarded for showing that the universe is not as simple as we might have thought!" [15]. And while we can dissect a frog to inspect its internal organs, and can inspect the interior mechanism of an elevator, the sub-atomic events in the interior of a physical thing are unobservable for theoretical reasons of Physics. Thus we can never empirically confirm or disconfirm, or even make it likely, by actual observation, whether the razor is accurate for even a single theory of sub-atomic events. We cannot even have a probability estimate of the razor's accuracy for a current theory of sub-atomic events. For no past sub-atomic theories were ever confirmed by direct observation of sub-atomic events.

In ordinary life, Science, and Philosophy alike, things are sometimes simpler than we think, but usually are far more complicated than we think. Thus in a historically progressive sense, the razor almost always turns out to be wrong. Ordinary life, Science, and Philosophy are all more complicated than we thought just twenty years ago, let alone a hundred or a thousand years ago. And that is a frequency probability argument against using the razor. Of course, that is only a general argument, and specific circumstances can greatly favour the razor. There are moments of great simplification in theory, when a Newton or Einstein comes along. But then we are back to discovering greater complexities as usual. And as T.H. Huxley is famously paraphrased, "There is nothing like a sordid fact to slay a beautiful [or for that matter simple] theory" [16].

No actual physical objects are constituted as simply as they *logically* could be. Or are we living in the physically simplest of all logically possible worlds? Indeed, it is logically possible for physical objects to contain no sub-atomic events at all. Likewise, it is logically possible for life forms to have no organs at all, and for elevators to have no interior mechanism at all. That is the razor's logical asymptote.

There is also a vicious infinite regress of interiors argument. Suppose we have two theories of an elevator that are empirically equivalent with respect to its external properties and behaviour, but one posits a simpler interior mechanism than the other. We then examine the interior mechanism, and it turns out theory (1) describes it accurately and theory (2) does not, so that theory (1) predicts our observations of the *interior* accurately and theory (2) does not. Thus the two theories are *not* empirically equivalent with respect to the *interior*. But even if we *had* looked at the elevator's interior, its interior *still* might turn out to be more complicated than we thought at the atomic level. Indeed, at the atomic level, even its *exterior* might turn out to be more complicated than we thought! For we could have two more theories that agree on the elevator's macro-exterior and macro-interior, but theory (3) posits a simpler atomic theory than theory (4), and another two theories about the sub-atomic level, another two about the sub-sub atomic level, and so on ad infinitum. (This does suppose infinite scientific analysability with no stopping point at absolutely primitive events.) And while all levels of events below the macro-level are unobservable *to us* for theoretical reasons, it is logically possible that each micro-level has its own micro-observers who *can* observe that level's events for theoretical reasons. And it is logically possible that the razor is wrong on every single level. In fact it *will* always be wrong, if things are always more complicated than we think. This also shows that the razor is not a logically necessary truth. For it is not true in all logically possible worlds. In fact, it is not true or false in any possible world, if it is an imperative.

To sum up my answer to question (2) so far, the razor is very limited in its helpfulness. It cannot help us with ontological or even epistemic issues. Its function is not to tell us how many objects exist, nor even to provide evidence for how many objects there are. Thus, in the absence of any other options, all it can do is serve the pragmatic function of counselling the selection of theories on the basis of simplicity, if there is no other reason to choose among them. And that *is* of huge importance in the practical world. In fact, we often have and can have no other reason to choose between two empirically equivalent theories. But we are only just getting started in our answer to question (2). For as I shall now show, there are at least 34 factors to be weighed in theory assessment, and the razor is only one of them. And there is no principled way to decide among the factors.

4. Fifteen factors in theory assessment

Ockham's razor is not the only factor in theory assessment. Far from it!

There are at least 33 other factors it can conflict with, and they should all be weighed and balanced together. For all of them, both individually and in combinations, logically can and often do limit/override/defence each other. In this section, I shall discuss fifteen factors.

Even on the score of simplicity alone, the razor is only one *kind* of simplicity. Quine speaks of "simplicity, familiar in ontological contexts as Ockham's razor" [17]. That is, the razor counsels us only about having the *ontological kind* of simplicity, that is, only about admitting as few entities as are needed to explain a thing. There are other kinds of simplicity to be weighed as well. And Quine admits that different kinds of simplicity can conflict [2, p. 188].

Quine admits Ockham's razor as a basic part of his larger program of simplicity in Science. The razor, as it is stated, is factor (1): lowest count of *entities*. Factor (2) is lowest count of *kinds* of entity. Factors (1) and (2) are different but distinct only in reason in the negative sense that 'no entities' implies 'no kinds of entities' and vice versa. And we may call (2) the kind-version of the razor. But the two factors can also conflict; think of whether we would prefer 70 rabbits or one lion to settle a matter for us! Of course, in Science and Philosophy alike, we usually shave kinds of entities.

Besides the razor, Quine's program of simplicity also includes at least two other kinds of simplicity: (3) "economy in the roots of theory" and (4) "brevity of paraphrase"; these differ enough that they sometimes conflict [2, p. 188]. But Ockham's razor really belongs to economy in the roots, insofar as the roots include the primitive terms of the theory. For to minimize the entity count is just to minimize the number of primitive terms the theory quantifies over. And to minimize the kinds-of-entity count is just to minimize the kinds of primitive terms. Besides the razor (1) and the kind-razor (2), economy in the roots (3) also includes (5) minimizing the number of axioms of the theory, (6) minimizing the number of rules for deriving theorems from the axioms, and (7) minimizing the number of rules for deriving predictions and retrodictions by applying the laws (the axioms and theorems) of the theory to observation statements. Thus there are at least five basic parts to economy in the roots.

Brevity of paraphrase (4) is reducing use of primitive terms by using definitions, that is, stating things in "mere shorthand", as opposed to always using the primitive terms ("longhand") [2, p. 188]. Factor (8) of Quine's simplicity program is the total elimination of primitive names by replacing them with definite descriptions á la Russell [2, p. 188]. Of course, (8) eliminates only the names, not the entities. And (4) eliminates the entities only on the eliminative interpretation of logical analysis.

Thus we already have eight factors to weigh. And we have only covered Quine's simplicity program so far! Some of the factors are of course overlapping, but they can still conflict. Factor (3), economy in the roots of theory, is a determinable with at least six determinates: factors (1)-(2), (5)-(8).

Quine also admits two other major factors. These are (9) the maxim of conservatism (preserving the bulk of existing theory) and (10) the principle of sufficient reason. Conservatism counsels minimizing changes to theory (9a), and

maximizing explaining the unfamiliar in terms of the familiar (9b). And the principle of sufficient reason states that every thing has a reason or cause. It counsels that a theory needs to account for every object that falls within its scope [2, 17]. Quine says that the principle of sufficient reason "is a rejection of the gratuitous" that is, of things that exist for no reason, that is, without explanation [2, p. 21]. Thus we now have ten factors to weigh and balance.

Are these last two factors kinds of simplicity? That is, can they be subsumed within the general program of simplicity?

Quine gets it wrong concerning the principle of sufficient reason. He thinks the principle "may be plausibly subsumed under the demand for simplicity, thanks to the looseness of the latter idea" [2, p. 21]. But the idea of simplicity is nowhere near that loose. The idea of entity count or kind of entity account is quite clear, and so are the other kinds of simplicity, such as axiom count or rules of inference count. They are all just counting the number of things! And the principle of sufficient reason is not about counting numbers of things at all. It states that every thing has *one* sufficient cause or reason, no more and no less. Thus here there cannot be a simpler count, nor a more complex one. That a thing or kind of thing can have different sufficient causes does not detract from this point. Fires can be started in many different ways, but each particular fire has its own unique sufficient cause. And if a sufficient reason is always the one and only sufficient reason, then it is both the simplest *and* the most complex sufficient reason, in the same way that the one and only apple on the plate is both the best apple and the worst apple on the plate. Once again, Quine is pounding a square peg into a round hole. In fact, that is always the result when we try to impose simplicity on things that are complex.

Sufficient reason is not at all the same thing as *simplest* reason. Indeed, a sufficient reason logically can be quite the opposite! A sufficient reason logically might be the most complex reason on offer. Look, there is a fire! But it is only an oily rag, so the simplest theory is spontaneous combustion. But if we had been there, we would have seen ten children all lighting the rag with matches for sufficient combustion. And even a simple rag is a complex set of micro-events. This is not to mention background factors as part of the sufficient cause. The rag would not combust on the airless moon.

Simplest sufficient reason is indeed a kind of simplicity. But that very statement is circular and begs the question. It is an empty tautology that says nothing. Thus it can only offer empty counsel. And as we just saw, the simplest sufficient reason on offer logically need not be the actual sufficient reason.

The principle that every entity has a cause or a reason for being is logically unrelated to the concept of simplicity. That an entity has a cause or reason implies nothing whatsoever as to whether either it, or its cause or reason, or anything at all, is simple or complex. Some causes and some effects are very simple, and others are very complex. Conversely, whether an entity is simple or complex implies nothing whatsoever as to whether it is a cause or an effect, or whether anything at all has a cause or a reason for being. This is especially obvious in the case of Natural science. For natural causes are logically

contingent, and that includes their simplicity or complexity.

In contrast, conservatism is very definitely a kind of simplicity. For it counsels precisely making the simplest change to theory. Quine says that conservatism is "a maxim of *minimum* mutilation" ([17], my emphasis). Thus conflicts between conservatism and (any other kind of) simplicity are really conflicts between two kinds of simplicity. Again, Quine admits that different kinds of simplicity can conflict; he gives the example of "economy in the roots of theory" and "brevity of paraphrase" [2, p. 188]. Here Quine's only mistake is one of presentation, insofar as he presents conservatism as a factor *in addition to* his general program of simplicity.

Quine gets something else wrong as well. On the one hand, he says that both simplicity and conservatism are epistemic. He says, "A normative domain within epistemology survives the conversion to naturalism.... The most general of its norms are perhaps conservatism... and simplicity." [17] But on the face of it, there is nothing epistemic about either simplicity or conservatism. On the face of it, both are merely pragmatic counsel, except insofar as the existing theory is supported by evidence. But a theory cannot be identified with the evidence that supports it, unless it is a self-evident theory.

Quine does not say the principle of sufficient reason is epistemic. Yet that is the only maxim that even appears to be epistemic. For to give a reason *is* to give evidence. Evidence is precisely something that makes a statement either more likely or less likely than we would *otherwise* find. And that is called its *logical relevance*. Evidence is defined as logical relevance both in John Maynard Keynes's [18] probability theory and in evidence law [19, 20].

Evidence is logically relevant regardless of whether its making a statement more or less likely than it would otherwise be rises to the level of reason to *believe* or *disbelieve*. For evidence can be too slight for that, and still be evidence. Of course, a sufficient cause or reason of the existence of a thing would be sufficient evidence to believe that the thing exists; but there can be other sufficient reasons to believe as well. If I see Smith murder Jones, I have sufficient reason to believe it; but my seeing it is not the cause of or (usually) the reason for the murder. It is merely the cause of and the reason for my belief. I mean logically sufficient reason to believe, not psychologically sufficient.

If I am right that conservatism is a kind of simplicity, and if Quine *were* right that simplicity is a kind of evidence, then conservatism *would* be a kind of evidence by implication. For that would follow by hypothetical syllogism (if A is B, and if B is C, then A is C). And the syllogism would be sound if both its premises were true; but one of its premises is false. For while conservatism is a kind of simplicity, simplicity is not a kind of evidence. Thus the fact that Quine fails to notice this syllogism is merely an in-house criticism. For the syllogism is in fact unsound, and it is merely the case that Quine is logically committed to admitting it as sound.

Quine overlooks something else too. He says that we know of no principled way to decide conflicts between simplicity and conservatism, and that here science is an art. For, so to speak, we know of no yardstick that could

measure such incommensurables. Quine says: "No general calibration of either conservatism or simplicity is known, much less any comparative scale of the one against the other. [Thus] there is no hope of a mechanical [decision] procedure.... [Thus theory formulation, as well as assessing which theory is best,] is an imaginative art. It is the art of Science." [17]

I think Quine is right. But that is only one conflict, between only two factors. Quine overlooks that the very same thing can also be said of any two factors or conflicting combinations of factors in assessing a theory. There is no yardstick, no principled way, to decide *any* conflicts among *any* combinations of factors. And that is quite a large number of kinds of possible conflict! We counted ten factors so far, and we will be counting 34 factors altogether, so the number of possible conflicts is basically 34 factorial.

There is at least one factor that Quine does not mention, even though it was published fifteen years before *Word and Object*. It is a maxim Quine might well reject; and in fairness, that might be why he does not mention it. It can scarcely be called a kind of simplicity, since it counsels the opposite of the razor. Yet neither is it a maxim that is logically unrelated to the razor. For it is the logical counterbalance to the razor. Kenneth Burke says, "Entities should not be *reduced* beyond necessity", any more than they should not be *multiplied* beyond necessity ([21], my emphasis). We may call this Burke's maxim, or the anti-razor.

Ockham's razor and Burke's maxim are equally valid, in that the real world logically can be *either* simpler *or* more complicated than we think. Each maxim is logically equal in its validity (advisability), and the validity of each is equally limited by the other.

Good scientists know that theories sometimes go too far in Ockham's direction. In fact, as a purely practical matter, sometimes they must. For example, Andrew Robinson says "any model [in Solid-State Physics] contains many unavoidable over-simplifications (in contrast, it is worth adding, to a theory like Special Relativity)" [22].

Arthur C. Clarke says there is a "well-known quotation supposedly from Einstein, 'Things should be made as simple as possible *but not any simpler*'" [23]. Alice Caraprice, editor of *The Ultimate Quotable Einstein*, has not found this saying in Einstein's writings [24]. Caraprice concludes, "Most likely, the quotation is a paraphrase of some of Einstein's other statements of simplicity, many of which can be found in this book" [24]. Stephen Hawking and Leonard Mlodinow expressly state that the saying is a paraphrase of Einstein. They say, "To paraphrase Einstein, a theory should be a simple as possible, but not simpler" [25]. And they make it plain that they agree with Einstein completely on this.

Thus we need to distinguish the ostensible quotation from the view it expresses. For regardless of whether the quotation is ever confirmed, Einstein does hold that view. Thus we may call the logical conjunction of Ockham's maxim and Burke's maxim 'Einstein's maxim'.

Einstein's maxim is merely pragmatic, if I am right that its two conjuncts are. For if the two conjuncts are merely pragmatic, then there can be no emergent ontological or epistemic property arising out of their merely logical conjunction. Thus I shall not count Einstein's maxim as a separately enumerated factor, since it is a mere conjunction of two factors that we have already listed.

Just as (1) Ockham's razor has (2) a kind-version, so Burke's maxim (11), the number of entities should not be reduced beyond necessity (the anti-razor), has a kind-version as well: (12) the number of kinds of entities should not be reduced beyond necessity (the kind-anti-razor). Thus Einstein's maxim is a logical conjunction of four factors, (1)-(2) and (11)-(12), if we include the two kind-versions.

All my criticisms of Quine are really just improvements of him. Basically, except for rejecting naturalism, I am just making his view even better. I corrected his classification of which factors belong to the simplicity program, and his view of which factors are epistemic. I showed that there are far more conflicts to be decided than just the one conflict he mentions between simplicity and conservatism. I also added an entirely new factor, Burke's maxim, to the list.

The proper function of Burke's maxim is pragmatic if and only if that is the proper function of the razor. For they are logical counterparts. Note that in the logic of imperative sentences, they are formal logical counterparts ('do this', 'do the contrary'). And on the face of it, there is nothing intrinsically epistemic about either of them. And if things are usually more complicated than we think, then Burke's maxim is better advice than the razor, based on simple frequency probability. We might even run a probability test to see which maxim, Ockham's or Burke's, is likelier to apply in a given case. If things are usually more complicated than we think (how often have we heard that?), then Burke's maxim would be likelier to apply to the next case than Ockham's. But neither maxim, considered in itself, is epistemic.

Einstein's maxim is really a 'Goldilocks' or 'golden mean' maxim. Namely, accept the theory that is neither too complex nor too simple, but just right. And that would be the theory that posits the true number of entities. But if a theory did that, then it would satisfy the correspondence theory of truth. And if the theory not only truly described the facts, but exactly corresponded to the facts in its logical complexity, then in the analytic tradition, such a theory would be called an ideal language, or a logically perfect language. That may be a practically impossible ideal. It may even be a theoretically impossible ideal in various senses of the term 'theoretically', such as 'in the present state of theory', or 'for human researchers like us'. But the correspondence theory is both intelligible and logically possible. And it is the theoretical ideal of Science and Philosophy alike in that logical sense. In any case, neither the razor nor Burke's maxim can *invalidate* the correspondence theory of truth concerning statements of how many entities there are. For their function is not to decide ontological questions, nor even to provide evidence. Their sole function is pragmatic.

If we wish to describe the 'metaphysical furniture of the world', surely we wish to admit neither more nor fewer entities than there actually are, and to describe the world as truly as we can. And even if Laplace is right that there is no need to postulate God to explain the world scientifically, God logically might still exist. Just like an elevator, the Universe might be more complicated than Laplace thinks.

One might object to the correspondence theory of truth that we can never get beyond the limits of our perception or thought to say how the world is in itself. I have two replies. First, if that is true, then that *is* how the world is in itself. And second, all the factors in theory assessment will have the same values regardless, so the objection is really irrelevant. And if it is logically relevant, then it is not even evidence.

In the history of Science and Philosophy alike, the general trend is that we are always discovering more complexity; and we often cannot reduce the complexity to theories as simple as we would like. Thus on the whole, intellectual history seems to favour Burke over Ockham. Sometimes there are great simplifications by great thinkers like Newton and Einstein. But data collection and the discernment of distinctions just keep on increasing in the background.

One might object that the early moderns' 'Cosmic Man', such that the whole Universe known to us exists inside a tiny part of his body, ought to be shaved because we have (and can have) no evidence of him. Note that he would be an *exterior* imperceptible object *for us*, since everything *we* can perceive would be internal to him. And there logically could be an infinite series of whole societies of ever-larger Cosmic People such that People on the same level can perceive each other, but People of any level n are too tiny or different to be perceptible to People of level n + 1. This merely inverts our previous series of levels of ever-smaller micro-events and micro-observers. That is, we ourselves would be Cosmic People to people whose whole universes are within our own sub-atomic parts, and so on indefinitely in both directions, with no people on any one level having any evidence of people on any other level.

My reply is that this is not a case of two empirically equivalent theories for *both* of which there is the same *positive* empirical evidence, but of two empirically equivalent theories (one admits Cosmic People, and the other rejects them) for *neither* of which is there *any* empirical evidence. And it is the *absence* of any evidence either for or against Cosmic People that favours the theory that rejects them. For there is no reason to accept Cosmic People at all. We might as well be weighing two empirically equivalent theories, one of which admits imperceptible unicorns and the other does not. Thus our reason for rejecting Cosmic People and imperceptible unicorns alike is not the razor, but the principle of sufficient reason. For if there is no reason at all, then there is no sufficient reason either. And the razor applies if and only if there is positive evidence for both theories. But then Burke's logical counterpart maxim applies if and only if there is positive evidence for both theories as well. And likewise for Einstein's maxim. For it merely conjoins Ockham with Burke.

I argued that the principle of sufficient reason is epistemic because A is evidence for B if and only if A is a reason (causal or not) for admitting B. If any other factor is epistemic, surely it is conservativism - not as such, but only insofar as the bulk of existing theory has evidence to support it. This brings us to a new point. Perhaps some *parts* of the bulk of existing theory are better supported by evidence than other parts. Yet it is logically possible that it is the less evidentially supported parts of existing theory, and not the more supported parts, that work better with a certain new theory and *its* evidence. Thus there can be conflicts between the two factors of (13) having better epistemic support from existing theory, and (14) working better with existing theory even if there is less epistemic support from it. Factors (13) and (14) logically cannot exist without, and thus are distinct only in reason from, (9) conservatism. But (13) is an epistemic factor (our third), while (14) is merely pragmatic.

Of the factors discussed so far, the epistemic factors, (9) conservatism (insofar as existing theory is based on evidence), (10) the principle of sufficient reason, and (13) being epistemically better supported by existing theory, clearly place substantive limits on the razor. For they are not merely pragmatic, but have actual epistemic value. The three overlap when we have more (10) sufficient reason to accept a theory when it is (13) better supported by the evidence for (9) existing theory.

Sufficient reason suggests the most important factor of all, (15) adequate explanation. For if theories A and B are empirically equivalent, and if A is simpler than B, but B provides an adequate explanation of the thing and A does not, then B is incomparably preferable. For what does it matter if A is simpler, if A does not adequately explain the thing? And to explain a thing is to explain it adequately/sufficiently/successfully/satisfactorily, even if there is such a thing as a partial (as opposed to full) explanation.

Adequate explanation logically includes sufficient reason. For how can an adequate explanation fail to provide sufficient reason for the thing's existence? And sufficient reason is sufficient evidence to believe. (Recall that to give a reason *is* to give evidence.) Therefore adequate explanation logically includes sufficient evidence to believe. And that makes sense, because how can an adequate explanation fail to provide sufficient evidence to believe?

It is really if and only if two empirically equivalent theories *also* equally adequately explain things that, other factors being equal, the simpler theory is preferable. But then we may as well say that the razor is to be used if and only if *all other factors* are equal. And that is just the caeteris paribus clause spelled out in more detail, with adequate explanation being the chief part of it.

Just what is adequate explanation? The general concept may be indefinable, since different kinds of theory may admit of different kinds of explanation; and the two main kinds, scientific and philosophical, arguably have never received (if I put it this way) an adequate explanation. Certainly there have been rival theories of explanation in Science and Philosophy alike. In fact, it would be circular to give an explanation of explanation. Still, we have a fairly good idea of what explanation is. We have plenty of examples of both good

explanations and bad ones. Thus we have a good idea of how to assess theories on how adequately they explain things, even though we have no adequate explanation of adequate explanation. In all these respects, explanation is much like definition. Can definition be defined? Can we give an adequate definition of adequate definition?

Laplace had no need of God to explain the cosmos *scientifically*. But philosophers can argue that Science fails to explain the world *adequately*, or even to explain why there is a world at all. And we can argue that we need to posit God to explain that. Stephen Hawking says: "The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe. Why does the Universe go to all the bother of existing? Is the unified theory so compelling that it brings about its own existence?.... Up to now, most scientists have been too occupied with the development of new theories that describe *what* the Universe is to ask the question *why*. On the other hand, the people whose business it is to ask *why*, the philosophers, have not been able to keep up with the advance of scientific theories." [15, p. 190]

Hawking is surely right to say that the question why the Universe exists at all, even if modern Cosmology correctly describes its self-origination from the quantum plenum, still can and ought to be raised. For even if the physical universe is self-generating, why is *that* the case? Why was there a quantum plenum for it to bubble up from? Indeed, why are the quantum laws the way they are? Hawking says the very laws of Nature could have been different, depending on how the Universe bubbled up [25, p. 140]. For the laws merely describe the uniformities of whatever process actually happens. (Note that all physical laws are logically contingent, and logically could have been otherwise.) Thus for Science to shave God may be to shave the whole question of why. It sounds a bit like sawing off the branch we are sitting on.

In any case, the single most important factor in theory assessment is adequate explanation. It is the sine qua non of all theory, scientific or not. For without it, all the other factors are useless and even irrelevant. For what do they matter if a theory does not even explain things?

Adequate explanation is distinct only in reason at most from the principle of sufficient reason. For what is the difference between an adequate explanation and a sufficient reason? Surely all adequate explanations are sufficient reasons, and the only question is whether all sufficient reasons are adequate explanations. And, perhaps as a purely hypothetical or even per impossible statement, some sufficient reason were *not* an adequate explanation, we would prefer the adequate explanation. For it would contain the sufficient reason plus something more that we wish to understand. In fact, this seems to occur whenever we have sufficient reason to admit *that* a thing exists, but do not yet understand *why* it exists. That is the 'something more' we want. And that devolves to giving the logically deepest, i.e. the most general, reason for the thing's existence. I shall explain that using philosophy of Mathematics, which often makes things clearer.

Aristotle argues that the true explanation is the one that states the *most general* true description. (Aristotle's term is the description of 'commensurate universality', meaning the most general description that applies.) For example, two lines are parallel not because a third line intersects them both at right angles, but because it intersects them at the same angle [26] (compare with [26, p. 96]). For we can eliminate the third line's intersecting the first two specifically at right angles, and the first two lines will still be parallel, if the third line still intersects them at the same angle. Aristotle also gives the example of an isosceles triangle the sum of whose angles is equal to two right angles, not because the triangle is isosceles, but because it is a triangle. For if we eliminate the property of specifically being an isosceles triangle, the sum will remain the same, if the figure is still a triangle. For we can eliminate the property of being specifically isosceles, and the sum will still be the same.

Here the idea would be that 'God caused the world' is the most general description and therefore the explanation of why there is a world. Whether that explanation is adequate or even true is another question. But if it is the only adequate explanation, then Science cannot use the razor to shave God. And certainly not if the explanation is true! Or can it be pragmatic to shave entities that are there?

It would seem that there cannot be two adequate explanations of a thing, for the same reasons that there cannot be two sufficient reasons for a thing's existence.

On the face of it, the other main epistemic principle, conservatism, is always outweighed by an adequate explanation as well. What does the bulk of existing theory matter if we now have an adequate explanation for the first time? Unless, of course, the bulk is part of the adequate explanation.

The razor and Burke's maxim have at least four things in common. First, they are merely counterpart pragmatic guides. Second, they both have exactly the same caeteris paribus clause, 'other things being equal'. Third, the chief part of that clause is the adequate explanation factor. For if a theory fails to explain things, it does not matter whether it posits too many entities *or* too few. We cannot even say the *reason* it fails is that it posits too many entities or too few, since the reason might be something else altogether. Notably, it may fail to predict. Fourth, the razor and Burke's maxim have in common that *all* the other factors belong to the caeteris paribus clause. The adequate explanation factor just weighs more than all the rest put together. For it is the sine qua non of theory assessment.

Since Einstein's maxim is the mere conjunction of Ockham's razor and Burke's maxim, it has these four things in common with them too. It is merely pragmatic. It has the same caeteris paribus clause. And that clause contains all the other factors, with adequate explanation outweighing all the other factors put together, much as Jupiter outweighed all the other gods at once. Thus we may say that the caeteris paribus clause's primary content is, 'Use no more entities than are necessary for an adequate explanation, and no fewer'.

Ockham's predecessors go back at least to Aristotle [26, p. 180]. Burke's predecessors go back at least to Walter Chatton, who was with Ockham at Oxford. Einstein's predecessors go back at least to Immanuel Kant, who admits both the razor and a counterbalancing maxim [27] and arguably back at least to Aquinas.

Alan Baker says: "There is no inconsistency in the coexistence of these two... principles, for they are not in direct conflict with each other. Considerations of parsimony and of explanatory sufficiency function as mutual counter-balances, penalizing theories which stray into explanatory inadequacy or ontological excess [Baker's footnote 23 appears here]. What we see here is an historical echo of the contemporary debate... concerning the proper trade-off between simplicity and goodness of fit." [4]

Baker says in his footnote 23, "Groarke writes: 'Ockham says: "Economical explanations are to be preferred." Chatton says: "Use as much explanation as necessary". We have then two sides of a sufficiency/economy principle'. In the same vein is Einstein's remark that "Our theories should be as simple as possible, but no simpler." [4]

This is correct as far as it goes, except that as we saw, Caraprice has not found Einstein's remark in Einstein's writings [24], and except that Baker mixes up what I have called Burke's maxim with adequate explanation. The razor and Burke's maxim are logically equidistant from adequate explanation, which outweighs both equally. It is not as if the factor of adequate explanation is on Burke's side. For both the razor and Burke's maxim contain it as the primary content of their identical caeteris paribus clause: 'Use no more and no fewer entities than are necessary for an adequate explanation'.

Centuries before Einstein, Aquinas accepted the thesis I called Einstein's maxim. For Aquinas does not wish to multiply entities beyond necessity, but he also wants a 'full account' that posits as many entities as are needed to explain a thing [28]. Aquinas describes the (pre-Ockham) razor as a reason to doubt God's existence in *Summa Theologiae*, Part 1, Article 3, 'Is there a God?'. He then states the Five Ways (his five arguments for the existence of God), and in effect concludes that we need to posit God if we are to explain why the world exists [28], much as Einstein concludes the same thing from the argument from design. Thus Aquinas accepts different levels of truth and Science (he argues that Theology is a science), just as he says in the very first Question in the *Summa Theologiae*.

5. Nineteen more factors

I shall now discuss the other nineteen factors I found. May others find more.

Einstein says "the theory must not contradict [existing] empirical facts", and he also requires positive "confirmation of the theoretical foundation by the available facts" [29]. These are our factors (16) and (17). If factor (16) refers to existing empirical facts, then it is different from but logically included in Karl

Popper's [30] famous requirement that a scientific theory must be falsifiable, that is, that it must be logically possible for an empirical observation to refute the theory. Popper's requirement is factor (18). It is a sine qua non of scientific theory, though not of philosophical theory. Factor (17) is consistent with the familiar observation that no scientific theory logically can be conclusively confirmed, since a disconfirming observation logically can always occur in the future. Factors (16)-(18) have degrees to be weighed; a minimal degree is a precondition of Science.

Einstein also says that one factor in theory assessment is: "what may be briefly but vaguely be characterized as the 'naturalness' or 'logical simplicity' of the premises ([i.e.] of the basic concepts and of the relations between these which are taken as a basis). This... has played an important role in the selection and evaluation of theories since time immemorial. The problem here is not simply one of a kind of enumeration of the logically independent premises (if anything like this were at all unequivocally possible), but that of a kind of reciprocal weighing of incommensurable qualities. Furthermore, among theories of equally 'simple' foundation that one is to be taken as superior which most sharply delimits the qualities of systems in the abstract (i.e., contains the most definite claims)." [29]

This gives us two more factors, (19) the naturalness of a theory's premisses (axioms), and (20) the containment of definite claims. Factor (20) is a sort of precondition of factor (18), falsifiability. For as a general rule, the more definite a theory's claims, the more falsifiable it will be. And if it makes no definite claims, then it is not falsifiable either. But naturalness is hard to understand. Is naturalness really the same thing as simplicity?

A little later in the same work, Einstein repeats that for him, simplicity and naturalness are the same thing. He says, "the inner simplicity, i.e. naturalness" [29, p. 29]. But I criticize Einstein for identifying simplicity with naturalness. The two concepts are very different. Not everything that is simple is found in Nature. Many have held both that God is absolutely simple and that God is not part of Nature, but is instead its Creator. And many have held that the simple hue, saturation, and brightness of a sensation of red are not to be found in Nature, which is colourless, but only in a mind. Even if these examples are incorrect, their intelligibility shows that the concepts of simplicity and naturalness are different. Conversely, very complex things are found in Nature: trees, animals, solar systems, galaxies, and most complex of all, human brains.

There is no principled way to assess the naturalness of a thing. There is no yardstick for measuring it, and no way to 'bean count' it. In fact, it is famously difficult to weigh naturalness and artificiality. A stock example is that of a violin and an electric guitar. Most people would say the violin is the more natural of the two. Yet electricity is a natural phenomenon, while violin polish is not. On the level of the whole instrument, violins and electric guitars are equally artefacts not found in nature. Yet a Stradivarius is far more deeply artificed than a cheap electric guitar.

Concerning scientific theories, if theory A is simpler than theory B, it does not logically follow that A more naturally fits the facts than B. It may be that A is *too* simple to be adequate, and pounds square pegs into round holes. Even if A and B are empirically equivalent, B can be more natural than A. For just as we have seen that simplicity is itself a complex concept and can be said in many ways, so naturalness can be said in many ways. For example, the terracentric theory far more naturally describes how we observe things from Earth than the simpler heliocentric theory. In fact, the main way the word 'natural' is used to discuss theories is to say that the theory naturally fits the data. And the main point is that neither being simpler as such, nor being a more natural fit as such, logically implies being the better theory. For there are at least 34 factors to be weighed in theory assessment.

Conversely, if theory A is more natural than theory B, it does not logically follow that A is simpler than B. In fact, B can be a very unnatural, artificially concocted theory, yet have logically simpler axioms and concepts than A.

Baker sums it up best when he says that in theory assessment, we seek to arrive at "the proper trade-off between simplicity and goodness of fit" [4]. I see no significant difference between goodness of fit and naturalness of fit. We are looking precisely for a good natural fit! And there can scarcely be a trade-off between simplicity and naturalness if they are one and the same factor. And unlike the razor and Burke's maxim, simplicity and naturalness are not logically equidistant from adequate explanation. For adequate explanation is more like naturalness of fit than it is like simplicity.

Einstein describes other factors: "A theory is the more impressive the greater the simplicity of its premises is, the more different kinds of things it relates, and the more extended is its area of applicability" [29, p. 33].

Here Einstein states three factors. First, the (20) simplicity (as opposed to naturalness) of the premises (axioms) includes our earlier factor (5), their being few in number, and (21) their being individually simple, which belongs to factor (3). Factor (21) includes simplicity of logical structure, and includes factors (1), (2), (4), and (8) as minimizing the number of primitive terms. The second and third factors Einstein describes will be our factors (22) and (23). Both concern the generality of scope of theory application. Factor (22) is to prefer including more *kinds of things* as related together, e.g. 'not only birds, but also bees can fly', while (23) is to prefer including more *things of the same kind*, e.g. 'more birds can fly than we thought'. Factors (22) and (23) logically cannot be sub-kinds of factor (10), the principle of sufficient reason, or of (15), adequate explanation. For generality of scope alone logically cannot provide sufficient or adequate explanations of anything. Even false theories have a scope! But (22) and (23) do concern *scope* of sufficient and adequate explanation, and in that sense they logically participate to a degree in (10) and (15). It is a bit like how things participate to different degrees in ideal forms for Plato, where sufficient explanation and adequate explanation are the ideals. Quine says "simplicity... is just what guides" the scientist to increase the scope of laws [2].

When Einstein says "there usually is agreement in judging the 'inner perfection' [i.e. simplicity and naturalness] of the theories and even more so concerning the 'degree' of 'external confirmation'" [29, p. 23-25], surely this involves a kind of insight that scientists share. And scientific insight involves two very different factors. For an older scientist who has much scientific experience may lack the native talent, ability, or intuition of a younger scientist, and vice versa. Thus we can and must consider the degree to which a theory is based on (24) scientific experience and (25) intuitive scientific ability. Of course, any experience-based *or* intuitive insight must be validated by empirical confirmation. For factors (24) and (25) do not help confirm or disconfirm evidence at all. But one might introduce an *external* evidentiary aspect to factors (24) and (25) by doing probability studies on how often the guesses of primarily experienced versus primarily intuitive scientists are empirically confirmed. This is much like our earlier probability studies of the razor versus Burke's maxim.

Einstein clearly admits factor (25). In fact, he admits it, not simplicity, as the factor of last resort. He says: "When two theories are available and both are compatible with the given arsenal of facts, then there are no other criteria to prefer one over the other except the intuition of the researcher" [31].

That scientific intuitions often conflict does not detract from the fact that factor (25) is a genuine and very important factor. Purely logical and mathematical intuitions often conflict as well; but without any such intuitions, Logic and Mathematics cannot even get started. Empirical observations and eyewitness accounts are famously conflicting and unreliable too; but science cannot even get started without them. If Einstein prefers (25) intuition over (24) experience as the deciding factor between empirically equivalent theories, that may be because intuitive insight is more directly cognitive. This may also go to naturalness.

But factor (25), scientific intuition, is not the same as factor (19), naturalness. For scientific intuition is located in the scientist, while naturalness is located in the axioms. And while there can be intuitions *of* naturalness, there can be intuitions about the other factors as well, and also about weighing conflicting combinations of factors. In fact, it is not possible for any such decisions *not* to be intuitive at bottom, since there is no yardstick to measure these things. Also, even if factors (25) and (19) are distinct only in reason, say if all naturalness is necessarily intuited, they are different factors in virtue of their very distinction in reason. And the same goes for any other factors which are different but distinct only in reason. It is a bit like the distinction in reason between red and colour. Where colour is a determinable and red is one of its determinates, pragmatic value is a determinable, and all the specific pragmatic factors are determinates of it. Likewise, simplicity, conservatism, and explanation are all determinables, each having several determinates as described in this paper. And there is no logical limit to the number of specific factors that are determinates of each, any more than there is any logical limit to the number of colours. Thus we can and must distinguish determinable factors from determinate factors. But mercifully, I shall not enumerate all these as different factors any more than I already do in

this paper.

Conservatism has two more sub-factors or determinates. For some parts of the bulk of existing theory can be better supported by the evidence than other parts. Yet it is logically possible that it is the less evidentially supported parts of existing theory that work better with a certain new theory and the new evidence for it. Thus there can be conflicts between factors (26/9c) having better epistemic support from the facts and (27/9d) epistemically better supporting, qua theory, a new theory. There is no yardstick for measuring these factors either. Of course, insofar as the parts of existing theory are themselves theories in their own right, all the factors apply to each of them. Q-theory, the current best candidate for a comprehensive theory that explains everything in Physics, is just a collection of overlapping theories.

I proceed to Quine and Ullian. One theory is more modest than another if it (28) asserts or claims less (this is not about scope, but about complexity of structure and about kinds of entities), or at least (29) makes less novel or more ordinary claims [7, p. 68-69]. Factor (28) is not only a factor in assessing scientific theories, but applies to assessing nondeductive arguments in general. For example, Irving M. Copi says, "A third criterion by which analogical arguments may be judged is the strength of their conclusions relative to their premises" [32]. The old adage is, 'To strengthen an argument, weaken its conclusion'. And that is just to draw a more modest conclusion. Factor (29) is related to (19) naturalness, and to (9b) explaining the unfamiliar in terms of the familiar. Quine and Ullian see modesty as blending into conservatism in one way and blending into simplicity in another. If so, then modesty is different but distinct only in reason from them both, on a continuum with them as the end points and modesty as the logically indeterminate middle.

Factor (30), refutability [7, p. 79-81], construed as admitting of degree, has Popper's falsifiability as its asymptote sine qua non. For without falsifiability, we do not have science at all. But insofar as there are *degree*s of refutability (or for that matter of confirmability), or questions as to which *parts* or *how much* of a theory is best judged to be refuted (or confirmed), refutability is a distinct factor to be weighed. For a merely falsified or refuted theory is false and refuted; but a complex scientific theory that faces a recalcitrant new observation (a sordid fact) logically can be adjusted in various different ways to accommodate the new observation [2, 7, 33]. And that too is a judgment call based on weighing all the factors. Factor (31) is ease (31a) or plausibility (31b) of theory adjustment to accommodate new facts.

Quine and Ullian's three other factors or 'virtues' of theories, simplicity, conservatism, and generality of scope [7, p. 66-79], are our factors (1)-(8), (9), and (22)-(23) respectively.

Factor (32) is being based on more observations of the same kind, factor (33) is being based on a greater variety of kinds of observations, and factor (34) is scientific rigor, or higher standards. These three factors are just general guides to probability.

6. Concluding overview

On the classical theist conception of God, God is absolutely simple. Indeed, simplicity is one of His infinitely many perfections! On that conception, we cannot simplify God any more than He already is. Of course, we simplify our theory if we exclude Him. But is that wise?

Whether God is empirically refutable is something of a mixed bag. We cannot discover God through a telescope. God is strictly irrefutable by scientific experiment. For he is not the kind of thing that can be discovered by scientific experiment. But theist mystics claim to experience God at least a little. And the Five Ways of Aquinas are mainly based on general facts of experience. Thus, oddly enough, God is empirically an issue in Philosophy and mysticism, but not in science. But it is not so odd when we consider what Science, Philosophy, and mysticism are. Mysticism can be subsumed here into Philosophy via the argument for God from mystical or divine experience.

From the scientific point of view, the main empirical argument for God is based on the observed harmony of Nature. This is the argument from design. Cicero and the Stoics discussed it in ancient times, and William Paley made it famous in modern times; but Einstein was its greatest scientific advocate [31, p. 324; 34; 35]. Einstein was not right about everything, and perhaps he was not a great philosopher. But his arguably being the greatest scientist who ever lived gives his acceptance of the argument from design a holistic, intuitive sort of great scientific weight. For not only did he find nothing in Science against God, but his deep scientific intuition into the harmony of Nature was precisely what led him to accept Spinoza's impersonal God, a conscious ultimate being who does not care about us, but who does create or sustain the Universe. And there is even some scientific weight in Isaac Newton's admission of a personal God who does care for us. By 'holistic' I mean there is no individual scientific experiment that can make the existence of God likely, but there is an overall sense of the harmony of Nature, derived from the study of Science, as being analogous to the design of a watch. And there is, if anything, even less of a principled way to weigh the holistic evidence for God than there is to weigh the factors for assessing scientific theories. Thus this is even more of a judgment call.

Can Science shave God? The main conflict of factors is the usual one: between the razor and adequate explanation. As we saw, Hawking notes that Science does not even concern the why, but only the that [15, p. 190]. And the usual explanation is that there are different levels or dimensions of explanation and understanding. What is adequate on the scientific level may be inadequate on the philosophical level. In fact, some of the great quantum physicists suggest that Science and religion are complementary levels, by analogy to the principle of complementarity of wave and particle descriptions in Quantum physics [36, 37]. As an intermediary logical step, some of them suggest that even ordinary living organisms cannot be adequately understood by Physics alone, and some sort of functional or teleological explanation is needed [36, p. 107-115; 37]. Shades of Aristotle! And surely Biology and Botany are closer to religion than

Physics is. This is perhaps especially clear in Arthur Schopenhauer's theory of the will to live as the ultimate reality, and as most clearly reflected in life forms [12-14]. Based on the intermediary step of admitting functional design in ordinary life forms, the argument for religious design may be more worthy than is sometimes thought. Of course, it is far easier to admit functional design in ordinary life forms than in the Universe as a whole, most of which seems quite lifeless.

As a final note, unlike simplicity, aesthetics (elegance or beauty) is *not* a factor in theory assessment. Again, philosophy of Mathematics often makes things clearer. As much as we admire either a simple *or* an elegant, beautiful logical proof, complex proofs can be just as sound. Thus the razor has no place in logic at all, and neither does aesthetics. Soundness of proof is not simplicity *or* elegance or beauty, nor are they soundness of proof. Einstein says, "matters of elegance ought to be left to the tailor and the cobbler" [38]. This is fatal to the poet John Keats, who proclaims in perhaps his most famous poem that "beauty is truth, truth beauty, and [this logically gross category confusion] is all ye need to know" [39]. For elegance is at least at least a kind of beauty. Nor is elegance the same as naturalness. For many natural things are profligate and wasteful. And as we saw, simplicity and naturalness are logically unrelated factors in theory assessment.

Compare two proofs that are offered. One is simple and elegant, but fails to prove the theorem in question. The other is more complicated, but does prove the theorem. Which proof would you accept?

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