



THE MULTIVERSE: A PHILOSOPHICAL INTRODUCTION

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Multiverses Compared—and Combined?

In the last three chapters, we have surveyed three proposed multiverses: from logic and philosophy, from quantum physics, and from cosmology. Each dizzies the mind. Each has powerful arguments in its favour: in the latter two cases, arguments that are in part empirical. But each is very controversial, since there are rival accounts of the phenomena it treats. (For the first multiverse, these are logico-linguistic phenomena like our commitment to modal language. For the second and third multiverses, they are physical phenomena.) And each multiverse proposal, for all its allure, raises major problems as well as solving some conceptual, indeed, philosophical problems. I have emphasized several such problems, and we have seen how these problems connect the different conceptions of a multiverse. I especially emphasized three problems prompted by the three multiverses in succession: What is a possibility? What is objective probability? And what is an explanation? These are difficult, live problems in philosophy.

So, I will *not* conclude the book by firmly endorsing, or firmly rejecting, even one of these multiverse proposals. This demurral is unsurprising given my previous admonitions that each of us must decide for ourselves what we can, or cannot, honestly believe, and how ambitious or modest is our intellectual temperament (cf. sections 3 and 4 of chapter 1). But there are three loose ends that I should tie up.

First, I briefly announced in section 2 of chapter 1 what I myself believe about the three proposals. Now that we have seen the details of chapters 3 to 5, I should say a bit more about my position (section 1).

Second, I said in section 6 of chapter 1 that all three proposals can make a good case that the different universes are isolated, i.e., unable to communicate with one another. So, again, now that we have seen the details of chapters 3 to 5, I should say a bit more about this, and about the more general topic of getting empirical evidence for a multiverse. I do this in section 2.

Third, I briefly announced that the Everettian interpretation of quantum theory prompts a proposal for what a possible world actually is. Namely, it is a branch of the Everettian multiverse, and so represented by a summand in the Everettian quantum state of the cosmos. (I mentioned this both in section 10 of chapter 3 (about Lewis' modal realism), and at the end of section 8 in chapter 4 (in my sketch definition of "world") and in the "Notes and Further Reading" section of chapter 4.) So, in section 3, I will discuss this proposal in more detail.

Finally, I will end with two salutary quotations (section 4).

1. What I Believe

I briefly announced in section 2 of chapter 1 what I believe about the three multiverse proposals. I said that I believe in the philosophical multiverse, but not the Everettian one, and I am undecided about the cosmological multiverse. As I put it, my verdicts are, respectively: "Yes, No, and Maybe." Now I give some more details, again, with the qualification "for what it is worth," since each of us must decide for ourselves what we can, or cannot, honestly believe (cf. sections 3 and 4 of chapter 1). I will again proceed in order, treating the philosophical multiverse in section 1, and then the physical multiverses in sections 2 to 4.

1.1 *The Philosophical Multiverse*

I believe in the philosophical multiverse. For recall from section 3 of chapter 3 that both in everyday thought and talk, and in technical science, we are up to our necks in modality. This commitment was further illustrated by my discussions of state spaces in physics, both classical (sections 3 and 8 of chapter 3) and quantum (sections 2 and 3 of chapter 4). And recall the benefits of explicitly accepting a realm of possibilities (of which the maximally specific possibilities are the possible worlds). Thus, sections 4 to 8 of chapter 3 paraded these benefits, for understanding not only everyday thought and talk but also technical science. (Besides, "understanding" might here

be construed ambitiously, as providing a conceptual analysis in the sort of sense discussed in sections 1 and 2 of chapter 3.)

But the benefits of this philosopher's paradise (Lewis' phrase, echoing Hilbert's homage to Cantor; cf. section 4 of chapter 3) do not require Lewis' own conception of it, i.e., his modal realist version of the philosophical multiverse (cf. the preamble and section 10 of chapter 3). Nor did Lewis believe the paradise required his modal realism. Rather, he advocated it as being, on balance, the best conception. Recall the problems and disadvantages of other conceptions that I reviewed in chapter 3's long section 9; in particular, subsection 9.3, and its objections (1) to (3) against the widespread view that the actual world is "concrete," while all the others are "abstract." On the other hand, I admitted that despite the strength of Lewis' arguments, I simply do not—cannot—believe his modal realist account. So, as in chapter 3 and the preamble above, I leave the nature of possibilities, in particular, possible worlds (and as I said, similar notions like proposition) as an open, and very difficult, problem in philosophy.

1.2 Contrasts with Physics

I turn to the two multiverse proposals from physics. The first, and obvious, point to make is that they have in common a contrast with the philosophical multiverse, a contrast that will be a recurrent theme in all the sections of this chapter. For since these proposals are prompted by physical theories that have been formulated to describe, explain, and predict empirical phenomena, they have, in contrast with the philosophical multiverse, both an apparent advantage and an apparent disadvantage—as follows.

First, they apparently could be supported by the specific empirical data that confirms the underlying physical theory (especially data that confirm those of its claims, which prompt, or are conceptually closest to, the multiverse proposal). Agreed, the philosophical multiverse is supported (on some or other account of it) by the great raft of all our commitments, everyday and technical, to possibilities, to understand such topics as semantics, counterfactuals, and determinism (and the others listed in sections 5 to 8 of chapter 3). But it is not supported by any data (even about what we say with modal language) with the kind of specificity enjoyed by a physical theory's evidence.

Second, on the other hand, any physical theory is a human construction, moulded by the scientific community's conceptual framework and the available evidence at a certain stage in enquiry. Therefore, any physical

theory is fallible, and all too likely to be superseded later on. The evidence that favoured the theory may later on be better accounted for—described and explained—by a successor theory. So, here lies, apparently, an advantage of the philosophical multiverse. For whatever the vicissitudes of physical theorizing, or more generally empirical enquiry, turn out to be, we can be sure that they will not overturn our great raft of commitments to possibilities (on some account or other).

(Of course, the vicissitudes of empirical enquiry might prompt us to give up specific modally involved claims, such as determinism, or notions like that of laws of nature. But that does nothing to dispose of the realm of possibilities that chapter 3 argued to be indispensable for formulating those claims and notions. Besides, we saw that this realm is indispensable for formulating claims and notions that are more everyday and less technical (such as reference and counterfactuals, discussed in sections 5 to 7 of chapter 3), and so surely less prone to be overturned by empirical enquiry.)

To be sure, we have seen this contrast before. We first saw it in general terms, in chapter 1's preamble and section 1. Besides, chapter 5 considered the idea of empirically confirming, not just the inflationary epoch, but also the ensuing multiverse proposal (cf. section 10 of chapter 5). And on the other side, my emphasizing that the inflationary epoch is still a speculation signalled that after all, the theory of inflation might in the future be superseded—and its multiverse thereby fall by the wayside. Nevertheless, it is worth stating this contrast explicitly here. For not only will it be a theme throughout this chapter. Also, although it was *not* developed in chapter 4, it will play a specific role in section 3's discussion of Everett.

So much by way of stating this contrast between the philosophical multiverse and the two multiverse proposals from physics. Let me now spell out a little how it applies to these two multiverse proposals. The results will be ambivalent and tentative, and they will lead to my stating that I cannot believe the Everettian one, but might be persuaded about the cosmological multiverse. Again, I will treat first the Everettian, and then the cosmological, multiverse.

1.3 The Everettian Multiverse

Chapter 4 emphasized that Everettians have yet to establish their interpretation of quantum theory. But it did not discuss how they could try to find evidence in its favour. I think it is clear that the broad strategy must have two components.

First, they need to show that even macroscopic systems, if strictly isolated, obey the Schrödinger equation, not some cousin equation as advocated by the dynamical reduction programme (cf. section 5 of chapter 4). This is, in essence, a challenge of experiment, not of theory. And it is a very daunting challenge, since even a few atoms in a vacuum chamber around the system, or even the photons, i.e., quantum particles of light in the CMB (cosmic background radiation; cf. section 2 of chapter 5), are enough of an environment to decohere a macroscopic system. And this will mean that the system's state (an improper mixture) prescribes probabilities for all possible measurements that match, or are very hard to discern from, the state predicted by a cousin equation advocated by the dynamical reduction programme (cf. chapter 4).

Second, Everettians need to refute the other no-collapse interpretations of quantum theory, which are also “one-world” theories, i.e., without a multiverse (as in the dynamical reduction programme). Section 5 of chapter 4 described the best-known example, the pilot-wave theory, and the “Notes and Further Reading” section of chapter 4 described others, such as the modal interpretation. This is likely to be a challenge of theory, at least as much as experiment: namely, to show defects, perhaps with an experimental signature, of those other interpretations.

So much by way of the first half of the above contrast: a physical multiverse's (here, the Everettian's) apparent advantage in being able to garner empirical support. I turn to the second half of the contrast: the apparent disadvantage that the physical theory in question (here, quantum theory) might be superseded, and its multiverse thereby fall by the wayside.

For quantum theory, we are in this regard in a very ambivalent position. The theory is stupendously well confirmed: it describes countless phenomena with stunning accuracy (i.e., to many decimal places), many of them phenomena that we can prove to be inexplicable by classical physics. But of course, this does not mean that it will never be superseded. And there are (at least) two broad grounds for believing that it will be.

The first is very familiar from chapter 4. Quantum theory's glorious successes are, in the last analysis, a matter of its predicted probabilities matching statistics gathered in experiments, which says nothing about the definiteness of outcomes in a single run of the experiment. In other words, the theory faces the grave embarrassment of the measurement problem. Though opinions about how to best solve it vary, many expect that only

some very basic changes in the theory can do so, and there is no reason to expect such changes to suggest some analogue of the Everettian multiverse.

The second ground for expecting quantum theory to be superseded has *not* (hitherto) been a topic of this book, though it is a staple of physics, and popular physics, literature. I mean the deep tensions between the concepts and detailed formalism of quantum theory and the concepts and formalism of general relativity (Einstein's theory of gravitation). For decades, these tensions have prompted efforts to formulate a new theory reconciling quantum theory and general relativity, dubbed "quantum gravity." These efforts have led to many deep insights, all sorts of proposed frameworks, and even theories, but none have won acceptance. And with one exception, these frameworks and theories do *not* suggest some analogue of the Everettian multiverse. (The exception is, of course, string theory, which I discussed in chapter 5, and will again here treat as an aspect of the cosmological multiverse.)

For me, the upshot of this discussion is that, as it happens, I cannot believe in the Everettian multiverse. For firstly, assuming that quantum theory (i.e., the Schrödinger equation, with no collapse of the wave function) is exactly true, I am nevertheless sufficiently sympathetic to solutions to the measurement problem other than Everett's (cf. the "Notes and Further Reading" section of chapter 4). And secondly, assuming that quantum theory will be superseded one day, e.g., to reconcile it with gravitation, the successor theory may well not suggest some analogue of the Everettian multiverse . . . But again, I say "as it happens" to signal that this is my fallible verdict. Each of us must make our own judgment about the evidence, both conceptual and empirical.

1.4 The Cosmological Multiverse

I turn to the cosmological multiverse. Again, I will lead up to my overall position by considering both the apparent advantage of a physical multiverse (here, the cosmological multiverse) that it can garner empirical support; and its apparent disadvantage that the cosmological theory (here, inflation and string theory) might be superseded, and its multiverse thereby fall by the wayside.

Indeed, chapter 5 discussed how cosmologists could try to find evidence for their theory, while recognizing that it is fiendishly difficult (cf. section 10 of chapter 5). This represented a contrast with chapter 4. But it is an unsurprising contrast, since the Everettian view is usually called—and

I called it—an *interpretation* of quantum theory. After all, it has no postulates or mechanisms beyond those of orthodox quantum theory (a parsimony that Everettians often advocate as an advantage of their view). On the other hand, inflationary cosmology is called a *theory*, albeit a speculative one, rather than an interpretation, precisely because it has postulates and mechanisms beyond those in the Big Bang theory of the 1970s. (It is called a theory (i) despite our having no agreed choice for what the inflaton field is or for its properties, e.g., the potential function; and (ii) independently of whether one invokes string theory to give a mechanism of the inflationary expansion.)

Broadly speaking, this contrast makes me more persuaded of the cosmological multiverse than the Everettian one. Hence my joke in section 2 of chapter 1 that for the cosmological multiverse, I say—with the film producer Sam Goldwyn—“a definite Maybe.”

Agreed, there are good reasons not to be so sanguine, some of which are reasons not to discriminate in one’s credence between the Everettian and cosmological multiverses. Here are four. (1) Although postulates and mechanisms may earn inflationary theory the honorific label of being “scientific,” rather than “interpretative” or “philosophical,” that by no means implies that there is any evidence in its favour. (2) Indeed, there is so far no evidence in favour of a specific model of inflation as against others. (3) Besides, inflationary theory might be superseded by a successor theory that “does away with” its multiverse, similarly to how, as I said above, quantum theory might be superseded, doing away with the Everettian multiverse. (Indeed, as one would guess, respectable rivals to inflationary cosmology without any multiverse have already been developed.) (4) We saw in sections 1 and 4 of chapter 5 (and its “Notes and Further Reading” section) the subtlety of the relations between the Everettian and cosmological multiverses, thanks not least to string theory’s central role in the latter. Such subtleties undermine this section’s contrast with the Everettian multiverse, i.e., my comparatively negative verdict about it, above.

So, you, of course, ask me: Why do I maintain this contrast? Here I must confess. I think the reason lies not in some objective superiority of the quantity or quality of the arguments and evidence, conceptual or empirical, for the cosmological multiverse compared with the Everettian one, but in two more instinctive points. The first is about intellectual history, the second about causal connections. So, the first is less technical and less internal to

the discussions in this book. But the second will return us to the subtleties of the relations between the Everettian and cosmological multiverses

First, over the more than five hundred years since Copernicus, we have learned various lessons that humanity is not central, or more generally, special, in the universe. First, the Earth was displaced from the centre. Then the solar system was discovered to lie in a “suburb” of the Milky Way, which turns out to be a disc, one hundred thousand light years across, of about one hundred billion stars. Then the nebulae (so-called since their images in telescopes were cloudy) were discovered to be yet other galaxies (with, on average, a hundred million stars). And there are so many other galaxies: nowadays, the number of galaxies in the observable universe is estimated to be between 200 billion and 2 trillion. In the light of these successive belittlements, it can seem a small step to accept that beyond the observable universe, there are other similar “vast expanses.”

Second, there is a contrast between the Everettian multiverse, as described in chapter 4, and the cosmological multiverse, which relates to causal connections. The former involves countless realities, each of which is vast and intricate, yet inhabiting the very same space-time as the apparent reality we know, being, so to speak, overlaid on it and not interacting with it. That seems very hard to believe, or even to get one’s mind around as a proposition, with a view to assessing its truth. On the other hand, the cosmological multiverse involves countless realities, each now vast and intricate, that *do* have causal relations with us, albeit very distant and convoluted relations. For they and the observable universe, which we now see, were “spawned together” in an unimaginably small and hot regime. This means that causal relations can, in principle, be traced by, so to speak, following a cosmic itinerary: starting from “our end,” one first traces back to the inflationary epoch, and then goes forward into (one or another) bubble universe. That branching web of causally connected regions seems easier to believe than the Everettians’ myriad co-present realities.

But I admit that these are both only instinctive points. Besides, the second, as I stated, uses chapter 4’s account of the Everettian multiverse, in particular, its sketch definition of “world” (cf. section 8 of chapter 4), which implicitly assumes a common background space-time “shared” by the different worlds or branches. But we saw in chapter 5 that there are ways to combine the Everettian and cosmological multiverse, especially by invoking the landscape of string theory (see sections 1 and 4 of chapter 5 and its “Notes and Further Reading” section). Such combinations may well

undermine my second instinctive point above, about a contrast of causal connections.

So, much by way of stating—for what it is worth—my own verdicts on the three multiverse proposals. But this last topic, causal connections, leads us back to my comment in section 6 of chapter 1, that all three proposals can make a good case that their different universes are isolated, i.e., causally disconnected. With the details of chapters 3 to 5 in hand, we can say a bit more about this. I now do this in section 2.

2. Why Don't We See the Other Universes?

The verb “see” is, of course, metaphorical. Our topic is not just vision, but other observable traces (effects or signs) of the other universes, which are, of course, part of the more general topic of getting empirical evidence for their existence, i.e., for a multiverse.

In this section, I will emphasize the Everettian and philosophical multiverses. I discuss them respectively in 2.1 and 2.2 below. My reason for this emphasis is that for the cosmological proposal, the topic of causal connections leads to details of advanced physics that are beyond this book's scope, while, on the other hand, for the Everettian and philosophical multiverses, a non-technical discussion is possible.

So, first, I will deal very briefly with the cosmological multiverse. For this, the causal connections between different universes were mentioned at the end of the last section. Namely, one can, in principle—very much in principle!—trace back in time within one universe to the inflationary epoch and then forward in time to another. Such a causal link is extremely tenuous. But what matters about such links is of course, not the second half of my description, the “forward in time to another universe,” but the idea that physical events within the different universes” common past, i.e., within the inflationary epoch, might leave some kind of observable trace in some (our?) universe that is a sign of the existence of the others. Indeed, there are proposals for how this could be. But they lie outside our scope (they involve such notions as primordial gravitational waves, and subtle imprints in the structure of the cosmic background radiation (CMB)). I only note that such traces would, of course, greatly aid the effort to confirm specific multiverse theories, an effort that we discussed in section 10 of chapter 5 in terms of statistical inferences from measurements of cosmological parameters.

2.1 Seeing an Everettian Universe? The Double-Slit Experiment

For the Everettian multiverse, the question “Why don’t we see the other universes?” can be answered with some details at the expository level we adopted in chapter 4. The relevant ideas are in section 7 of chapter 4, about decoherence, and in section 8 of chapter 4, about using decoherence to define the Everettian’s universes (i.e., worlds, branches).

The first point we need from section 7 of chapter 4 is that the difference between a superposition (superposed quantum state) and a mixture (mixed state) is encoded in numerical differences between the probability distributions that the two states prescribe. These differences are called “interference terms.” Here, the word “interference” doesn’t connote disturbance, but comes from the physics of waves. For when two peaks of two waves, e.g., water waves, meet to form a yet higher peak, we say the waves interfere constructively. Similarly, when two troughs meet to make a yet deeper trough, and when a peak meets a trough, so that they form a level surface, we say the waves interfere destructively.

What section 7 of chapter 4 did not say—I was in a hurry to expound decoherence—is that there is a paradigm experimental set-up that exhibits these ideas, and this set-up helps answer the question about not seeing other universes.

Indeed, there is both a classical and a quantum set-up, both called “the double-slit experiment.” The classical version may well be familiar from school physics. The quantum version is famous. It began as a thought experiment, or teaching device, to illustrate that the quantum wave function indeed behaves like a wave, but it has also been realized in the laboratory.

The classical version is a shallow pool of water, across which lies a barrier with two small slits. On one side of the barrier, a wave machine generates a “train” of waves moving toward the barrier, each wave parallel to the barrier. As a result, on the other “downstream” side of the barrier, from each slit there flows a train of circular waves. These two trains spread out, meeting each other—and interfering. If we put a screen parallel to the barrier on this downstream side, at a suitable distance, we can see the interference pattern of doubly high peaks and doubly low troughs.

The quantum version again has a barrier with two slits, on one side of which an “electron gun” fires a train of electrons, each with the same definite (or nearly definite) momentum, straight ahead toward the barrier.

(Although the apparatus, of course, exists in three-dimensional space, we can arrange to make a better analogy with the two-dimensional classical pool of water, with the slits being indeed not holes, but narrow slits extending in the third dimension.)

The definite momentum means that the wave function of each electron is like a train of waves, all parallel to the barrier. As a result, on the downstream side of the barrier, there emerges from each slit a circularly symmetric wave function, i.e., a train of semicircular waves. The two trains interfere, and we can see the interference pattern on a suitably placed screen. Indeed, even if we arrange for the electron gun to emit electrons intermittently, so that at any one time there is at most one electron in the set-up, there is an interference pattern.

(Each individual electron makes a dot, a scintillation, on the screen, which is like a TV screen, so the pattern builds up gradually, showing bands (lying along the third dimension) that each consist of many closely spaced dots, alternating with bands without any dots. Of course, the transition from the spatially extended wave function to the localized dot is the notorious collapse of the wave function, which is at the heart of chapter 4's measurement problem.)

This interference pattern indicates that the state of each electron as it passes through the barrier is a superposition—namely, of passing through each slit—so that the wave function shortly afterward is the sum of the two circularly symmetric wave functions, each centred at a slit.

For if each electron definitely passed through just one slit, one would expect the screen to show, not an interference pattern with its many alternating bands, but just two “humps” (clusters of dots): one with its peak, i.e., most-closely spaced dots directly behind one of the slits, and the other with its peak directly behind the other slit. Such a two-hump pattern corresponds not to a superposition, but to a mixture of going through one slit and going through the other. (And if it is a 50-50, i.e., equi-weighted mixture, we expect an experiment with many runs, i.e., the gun firing many electrons one after another, to produce two humps with approximately equal numbers of dots.)

So much by way of expounding the double-slit experiment. I can now say how it helps answer the question about not seeing other universes, i.e., our not detecting other Everettian worlds or branches. We only need to recall section 7 of chapter 4's main theme, viz. decoherence. Recall that as a result of the rapid and ubiquitous process of decoherence, the states of

macroscopic objects are (very close to) mixtures of states that are definite for quantities, like position, that we intuitively want to be definite to solve the measurement problem. Applying this to the double-slit experiment, decoherence effects (for example, collisions with air molecules downstream of the barrier, which would amount to a probe system monitoring through which slit the electron passes) would produce a mixture, i.e., the two-hump pattern. Putting it the other way around, the double-slit's interference pattern is realized in the laboratory by making sure, by clever engineering, that decoherence does not smear the pattern into two humps. For example, the chamber needs to be a nearly perfect vacuum, with almost no air molecules.

But we also saw that Everettians define their universes (worlds, branches) in terms of the definite-valued states that are the components of the mixture obtained from decoherence (cf. section 8 of chapter 4). The upshot is that for all the countless macroscopic objects and set-ups that are *not* cleverly engineered within a quantum physics laboratory to be shielded from decoherence, the interference terms characteristic of a quantum superposition are strongly suppressed, so that within a single universe (world, branch) there is no observable evidence of other universes. Putting it, again, the other way around, one can think of the double-slit's interference pattern as revealing, to the perspective of the “mini-universe” that is defined by being definitely at one slit, the existence of the other “mini-universe” defined by being definitely at the other slit.

2.2 Seeing Other Logically Possible Worlds? Lewis' Answer

I turn to the philosophical multiverse. For this proposal, this section's question, “Why don't we see the other universes?” seems at first confused. For one's first thought is: whatever we eventually conclude about the exact nature of possible worlds in chapter 3's sense—about which chapter 3 ended in anxious agnosticism—they will surely *not* be the sort of entity that can be seen, i.e., observed, one from another. More generally, they will surely not be the sort of entity that has causal relations from one to another, or from one part (i.e., event, state of affairs) within one world to another part of another world.

Broadly speaking, this misgiving—one might even say, accusation—is surely right. But it is nevertheless worth pressing the question. There are two aspects to this. First, the question prompts one to ask what causation is and how it relates to possibility. Second, for chapter 3's great advocate of

possible worlds, David Lewis, the question *is* germane, and he had a full and interesting reply to it. I will address these two aspects in turn.

I will treat the first aspect more briefly. For to say more would need a thorough discussion of what causation is. But we can surely agree that causation is a relation between localized matters of fact. Here, my phrase “localized matter of fact” is intended to be neutral between various more specific conceptions that philosophers have advocated as being the relata of causation. (These conceptions are often given everyday words, like “event” or “state of affairs,” as labels; but used thus, the everyday word becomes a technical term of art.) And once we accept that the relata of causation, causes and effects, are localized matters of fact, then two reasons to *deny* that there can be causation from one possible world to another present themselves as plausible. I prefer the second reason.

First, one might invoke the distinction between “concrete” and “abstract,” and then maintain that (i) actual matters of fact (events, states of affairs) are concrete, while non-actual ones are abstract (in line with section 9.3 of chapter 3’s suggestion that a possible world is a sentence, or a set of sentences, or something similar), and (ii) that causation requires its relata to be concrete. From these tenets, it obviously follows that there is causation only within the actual world. But I think this line of thought stumbles. For first, if there is indeed no causation at non-actual worlds, how are we to understand our many (surely true) statements about possible causes and effects, such as “this short-circuit could have caused a fire”? This line of thought apparently vetoes understanding such statements using possible worlds. Second, and more fundamentally, the distinction between concrete and abstract is not in good order—as I urged, following Lewis, in section 9.3 and section 10 of chapter 3.

Second, one might say that causation requires its relata to be spatio-temporally related to one another, i.e., to be at some spatial distance and temporal interval (both possibly zero) from one another. Notice that this requirement is vastly weaker than requiring these relata, a cause and an effect, to be contiguous (adjacent) in space and time, as demanded by the principle of contact action (cf. section 2 of chapter 2). In particular, this requirement makes no prohibition against action at a distance as in Newton’s theory of gravity (cf. section 3 of chapter 2). It also admits, as one surely should, causation in non-actual worlds (more precisely, in those worlds that have a space and a time), unlike the last paragraph’s line of thought. Besides, it secures the desired answer to our question, i.e., the verdict that there is no causation

between possible worlds, provided no two parts of two different worlds are spatiotemporally related to each other . . . which for the philosophical multiverse, though not, of course, for the Everettian or cosmological one, seems plausible.

So much by way of general discussion of causation and how it relates to possibility. I turn to what I called the second aspect: How chapter 3's great advocate of possible worlds, David Lewis, answered this section's question, i.e., argued that there is no causation between possible worlds. His answer is interesting, for three reasons, of which the first two relate to the last two paragraphs.

First, after he meticulously formulates several disambiguations of the concrete/abstract distinction (a distinction which, as we have discussed, he diagnoses as multiply ambiguous), he admits that on most disambiguations, worlds are indeed, according to him, concrete. So, (following the first line of thought above) this conclusion would seem to exacerbate the threat of causation between worlds.

Second, Lewis argues, quite independently of the topic of causation, for the proviso at the end of the general discussion above, that no two parts of two different worlds are spatiotemporally related to each other. (His argument, in short, is that the overall best definition or conceptual analysis of what it is for two objects to be in the same possible world is precisely that they are spatiotemporally related.) So, that meshes well with my sympathy to the second line of thought above, that causation requires its relata to be spatiotemporally related to one another.

Third, Lewis has, independently of all his views about possible worlds, a theory of causation. And this provides fuel for a *proof* that, according to this theory, there is no causation between worlds. I will not go into details about this proof. For us, it suffices to say that his theory analyses causation in terms of counterfactual conditionals about the cause and effect, along the lines of "If the cause had not occurred, then the effect would not have occurred." Here, he understands the counterfactual conditional in terms of similarity between worlds, i.e., along the lines of the logical theories invented by Stalnaker and Lewis himself (and expounded in section 7 of chapter 3). But in any case, his proof that there cannot be causation between possible worlds would go through, i.e., remain valid, if one instead adopted various other semantics for counterfactual conditionals.

Furthermore, it is interesting for this chapter's purposes, viz. comparing the different multiverse proposals, that the above three reasons come

together, as Lewis realizes very well. For he ends his discussion of my second and third reason with a passage in which he explicitly says that—while he has proven that there is no causation (nor any spatiotemporal relations) between objects (or localized matters of facts, like events and states of affairs) in different possible worlds in his logical, i.e., chapter 3’s sense—he is very open to causation between what an Everettian or cosmologist might call two different worlds (in our terms: different universes), each a part of what for Lewis is a single possible world. Agreed, he does not cite Everett or the ideas of inflation; rather, he mentions science fiction. But the intent is clear.

Besides, he says all this vividly, indeed wittily, in his main book about possible worlds, *On the Plurality of Worlds* (1986). So, let me end by quoting the passage. After this section’s back-and-forth of reasons for and against various claims, a tiring ping pong of dialectic, it is a relief to read:

But if you would like to see a world where Napoleon conquered all, don’t give up hope. Maybe ours is one of those big worlds with many world-like parts, spatiotemporally related in some peculiar way. Then you might get your wish, near enough, by means of a special telescope or a special spaceship that operates entirely within our single world. You won’t see the world-like part where Napoleon himself is, of course; you’re there already, and he didn’t conquer all. But I presume you’d be content with a world-like part where the conqueror was an excellent counterpart of Napoleon. I would be the last to denounce decent science fiction as philosophically unsound. No, tales of viewing or visiting “other worlds” are perfectly consistent. They come true at countless possible worlds. It’s just that the “other worlds” that are viewed or visited never can be what *I* call “other worlds.” (Lewis 1986, end of section 1.6).

3. One Reality to Rule Them All?

Recall that chapter 3 left unresolved the hard question of what exactly a possible world is. But as I mentioned there (in section 10 of chapter 3), and reported in section 8 of chapter 4 (and in chapter 4’s “Notes and Further Reading” section), the Everettian interpretation prompts a proposed answer. Namely, a possible world *is* a branch of the Everettian multiverse—and so

is represented by a summand in the Everettian quantum state of the cosmos. In this section, I briefly discuss this proposal. (I will confine myself to chapter 4's account of the Everettian multiverse, setting aside the subtleties arising from cosmology, which we saw in sections 1 and 4 of chapter 5.)

My discussion is brief, not least because a recent book by A. Wilson develops and defends the proposal (cf. details in this chapter's "Notes and Further Reading" section). First, in 3.1, I will state the proposal. Then, in 3.2, I will discuss how it overturns the view, commonplace among philosophers, of the relations between logic and physics, and I'll make a specific objection.

3.1 *Wilson's Proposal*

The proposal begins by adopting chapter 4's Everettian multiverse. This involves not just the "one-liner" idea (in section 6 of chapter 4) that to each possible outcome of a quantum measurement, there corresponds a branch (or world or universe—and maybe many such). But it also involves the appeal to decoherence to more precisely define the branches (sections 7 to 9 of chapter 4), and the appeal to indexicality and decision theory (sections 11 and 12 of chapter 4, respectively) to make sense of probability, and, in particular to justify the Born-rule probability assignment. (In this section, it will be clearer to talk of Everettian branches, rather than worlds (or universes), for then I can reserve "world" for use in the phrase "possible world," and thus signal the connotations of chapter 3's concern with modality.)

So, there is what chapter 4 calls "the quantum state of the cosmos" (usually called in the literature "the universal quantum state"). It has countless decoherent branches. Countless of those *are* (not merely correspond to—for the Everettian) macroscopic realms of the sort we imagine or mention in our modal thought and language. Suppose, for example, that we make a counterfactual supposition, either in everyday thought and talk or in technical science. To take section 9 of chapter 3's example: we suppose that Butterfield is in Rome in August 2024, by saying "If Butterfield were in Rome in August 2024, then . . ." Or we suppose that kangaroos have no tails, or that planet Earth does not exist.

Now the proposal is as plain as day. Namely, these branches or realms *are* the possible worlds that give, along the lines of chapter 3, the semantics, the truth conditions, of our modal thought and talk. For example, let us consider counterfactual conditionals and adopt the Lewis-Stalnaker semantics for them (cf. section 7 of chapter 3). And let us consider "If Butterfield were in Rome in August 2024, then he would be on holiday," as said by me or you

(in the actual branch containing us both). The proposal is that this is true (at the actual branch) if the branches that are most similar to the actual one while making true that Butterfield is in Rome in August 2024, also make true that he is on holiday there and then.

(Of course, the Everettian branches of the sort we imagine or mention in our modal thought and language are just a subset of all the branches, probably a small subset in some precise sense of “small.” That is, there are countless other decoherent branches that correspond, *not* to anything we imagine, but to much weirder possibilities for which we have no appropriate words and concepts.)

And similarly for other aspects or topics in our modal thought and talk. Thus, the proposal is that (i) we should transcribe logical and semantic accounts of various phenomena, conceptual and linguistic (including in technical science), from the sort of framework expounded in chapter 3 to that of chapter 4, replacing “possible world” by “Everettian branch”; and (ii) by doing this, we get an account of the phenomena that is, not just tenable, but superior to others—that is, superior provided we accept the truth of the Everettian interpretation of quantum theory.

Evidently, this proposal is bold. It brings into contact, and comparison, with each other two detailed frameworks (and their literatures), which were developed to answer very different questions from each other. Besides, it claims that this comparison succeeds in the sense that the two sides mesh. More precisely, there are on the logical side (cf. chapter 3) accounts that, once transcribed, fit the Everettian interpretation of quantum theory well.

I will not go into great detail. But for this book’s topics, I should report that, as it turns out, several of these accounts, which, once transcribed, fit Everett well, are Lewisian accounts. So—such is Lewis’ influence—they are familiar to modal logicians and philosophers of modality. Here are two examples.

1. Lewis’ account of “actual” as indexical (in the sense of section 11 of chapter 4, used to explain Everettian probability) fits well, once transcribed. Thus, Lewis says that “actual” is indexical, referring to the world of the speaker/thinker, in just the same way that “now” refers to the time of the speaker’s/thinker’s words or thought, and “here” refers to the place of the speaker’s/thinker’s words or thought. Once transcribed, this becomes: “actual” refers to the branch of the speaker/

thinker, which fits well the Everettian's treatment (cf. section 11 of chapter 4) of an agent's uncertainty about the outcome of an imminent quantum measurement.

2. Lewis' account of determinism and indeterminism fits well, once transcribed. Recall from the last part of section 8 of chapter 3 that the broad idea of determinism is determination (i.e., supervenience) of the sequence of the system's future states by the system's present state, taken together with the sequence of all its past states. (A stronger formulation says: determination by the present state alone. But here, little will turn on this variation of the broad idea.) Recall also that Lewis accepts the idea of a law of nature (cf. section 6 of chapter 3), and therefore the idea of the conjunction of the laws of nature at a given possible world, say w , or what we might call "the theory of w ." (Here we recall section 4 of chapter 1's spectrum of confidence through to caution about contentious concepts; so, Lewis is confident.) With these ideas in hand, one then has two possible formulations of the claim that the theory of a given possible world w is a deterministic theory (and correlatively, that it is an indeterministic theory). Lewis argues in favour of the first.

First, one can say the theory of w is deterministic if and only if among all the possible worlds that share with w their laws of nature (i.e., their "theory of the world"), if two such worlds utterly match each other at each time up to a given time, then they also match at each and every later time. Note that this formulation allows for many such matching pairs of worlds. For it requires only that for worlds with the same theory of the world as w , their utterly matching on an initial segment of history up to a given time implies their also utterly matching at all later times. Correlatively, indeterminism is a matter of there being at least one pair of worlds that utterly match up to a time, but do not match at some later time (maybe many later times). Lewis proposes a phrase for indeterminism in this sense. He calls it a "*divergence of worlds*."

On the other hand, there is another possible formulation, which is clearest to state for the idea of indeterminism. Namely, that a *single* world (among those with the same theory of the world as w) at some time *splits*,

in the sense of itself having two or more sequences of later states. So, in the simple case of a single splitting in two, one can picture such a world, with time going up the page, as a “Y.” There is a single “thread” until a time, and thereafter two threads. Thus, Lewis’ proposed phrase for this meaning of indeterminism is “*splitting* of worlds.”

In chapter 4’s discussion of Everettian branching, I did not distinguish these two meanings—there was plenty else to discuss . . . But it is clear that, however exactly the Everettian defines branches (called “worlds” in section 8 of chapter 4), the distinction of meanings carries over, which prompts the question of whether an Everettian should be a “diverger” or a “splitter.” I will not go into this. Suffice it to say that there are good reasons to be a “diverger.” And furthermore, some of those reasons are what I have called the transcriptions of Lewis’ reasons to be a diverger within his possible worlds framework.

So, to summarize the proposal, it compares two multiverses that are apparently very different, having been developed to answer very different questions. And it makes a detailed case that the bold identification of possible worlds with Everettian branches is correct. The evidence for this is the fact that several correspondences of ideas that are implied or suggested by this identification, e.g., correspondences about indexicality and about indeterminism, work out very well.

3.2 Assessment

So much by way of summary. I now turn to assessing the proposal. I will entirely set aside misgivings about the Everettian interpretation of quantum theory. These were discussed in chapter 4 and do not need to be repeated. And I will focus on the proposal’s main idea, the identification of possible worlds with Everettian branches, not on details, such as my examples of indexicality and indeterminism. I will start with generalities and then end with a specific objection.

The first thing to say is that this is an utterly *naturalistic* account of modality. The entire realm of modality—all the possibilities imagined in our counterfactual suppositions, and the countless others that we never imagine—is to be incorporated into the physical cosmos as nowadays described by quantum theory. There could hardly be a more radical, indeed breathtaking, “takeover bid” of the subject matter of logic and semantics, the traditional preserve of logicians and philosophers, by another discipline.

Not by physics itself, of course, but by another band of philosophers, viz. the philosophical interpreters of quantum theory.

It is worth setting this takeover bid in the wider context of the usual view of the connections between this book's three proposed multiverses. On this view, the logical and semantical investigations that prompt chapter 3's "philosophers' paradise" of possible worlds are—if not wholly *a priori*, then at least—independent of the contingent discoveries of physics or other empirical sciences. So, whatever our answer to chapter 3's anxious question about the nature of possible worlds eventually turns out to be, the framework of possible worlds, the "philosophers' paradise," provides a vast reality, an empire, in which physics and other sciences take their place as, so to speak, a province. They investigate an aspect of reality, namely, the contingent details of how the actual cosmos works. But they are not "the whole story." And while physics may discover a multiverse, whether Everettian or cosmological or both, that physical multiverse is *all within* the one actual possible world (i.e., cosmos), in the sense of chapter 3's framework.

This usual view is undoubtedly the one that would be endorsed by the vast majority of logicians and philosophers. After all, it accords with the traditional, indeed centuries-old, idea that logic and philosophy investigate features of reality that are very general, independent of the details of observation and experiment, and maybe even *a priori*; whereas the sciences investigate specific and presumably contingent features, via detailed observation and experiment.

Obviously, this proposal's takeover bid completely denies this view. And speaking for myself, I confess that for that reason, I resist it. That is, even if I assume the Everettian interpretation of quantum theory, I still believe sufficiently in the autonomy, generality, and maybe even *a priori* status of logic, and, in particular, of logical investigations of modality, to *not* incorporate all the possible worlds as "mere" branches in the quantum cosmos. I would rather suffer anxiety from my not knowing how to answer chapter 3's question about the nature of possible worlds than have quantum physics take over logic.

Of course, this confession accords with the Humeanism I admitted in various passages of chapters 1 to 3 (especially sections 5 and 6 of chapter 2 and section 6 of chapter 3): both my acceptance that the results of science, in particular, the laws of nature, are contingent, and more generally, a low-key or modest estimate of the kind of understanding that human enquiry can secure.

It is also worth noticing a consequence for this proposal of the two facts (discussed in section 1 above) that (i) the Everettian interpretation has not been established, and might one day be agreed to be wrong, and another interpretation might be endorsed, and (ii) quantum theory (as a physical theory, however interpreted) may one day be superseded. These facts imply that this proposal's official semantics for our modal talk, e.g., counterfactual conditionals, is a hostage to fortune. If (i) the Everettian interpretation is one day discarded, or (ii) quantum theory is superseded by a successor theory with no multiverse that could supply the truth conditions of our modal talk, then the proposal's advocate will have to concede that their semantics has been refuted by the progress of physics—and that a new semantics must be formulated. (For they could hardly say that their semantics remains right, i.e., that we have for all these centuries been talking modally about the strictly fictional multiverse of a twentieth-century physical theory that has just been refuted.)

This consequence, that semantics could be refuted by physics, is worth noticing, since it makes vivid how opposed the proposal is to the usual view of the relations between philosophy and physics. But agreed, I do not intend this consequence as an objection. Indeed, the proposal's advocate is likely to be so steeped in naturalism as to take this consequence in their stride, or even as a positive advantage of the proposal.

Finally, here is a specific objection to the proposal. The idea is that the proposal conflicts with the contingency, not just of the laws of quantum theory (in particular, the Schrödinger equation), but also of two features much more specific and particular than the theory's laws: namely, the physical state of the quantum cosmos, and the forces operating within it. (These forces are encoded in a term in the Schrödinger equation, the Hamiltonian.) Of course, a Humean like me will want to take the laws of quantum theory as contingent (cf. section 5 of chapter 2 and section 6 of chapter 3). But it is not only Humeans like me who endorse the contingency of the other two features, viz. what the state is and what forces are operating. For non-Humeans, including those who say that the laws of nature are necessary, can and almost always do agree that both the state of a system and the forces acting on it (e.g., causing changes, determining its future evolution) are contingent: they could have been otherwise.

Thus, the objection is as plain as day. The proposal implies that “a lot more” is necessary than is usually believed to be necessary. Not only does it imply that the laws of quantum theory are necessary. Non-Humeans about

laws, who accept quantum theory (as they should!), might well accept that. But the proposal also implies that the quantum state of the cosmos (usually called the “universal quantum state”) could *not* have been other than it is. For according to the proposal, the state defines, via its set of decoherent branches, what is possible. And here, “what is possible” means—*not* what is nomologically possible in the restricted-modality sense explained at the end of section 6 of chapter 3—but what is possible *tout court*. Such necessity is hard to believe. Similarly, the proposal implies that the forces operating within the quantum cosmos (encoded in the Hamiltonian that, as I stressed in chapters 4 and 5, nobody knows how to write down!) could *not* have been other than they are. That is also hard to believe.

There is also an ancillary problem. This necessity of the quantum state, and of the operative forces, also threatens to cause trouble for the second issue raised at the end of section 8 of chapter 4. I mean the Everettian’s need to allow that the factorization of the cosmos’ state space, into the factor (component) state spaces for the various macrosystems, depends on what the overall state is. In section 8 of chapter 4, we saw that this allowance promised to give the Everettian the wherewithal to secure the fact that there surely could have been different macrosystems than there, in fact, are. This fact seems a “non-negotiable” fact of our modal thought and talk. After all, we say things like “I might have had more children.” But if the quantum state of the cosmos is necessary—given “once and for all” in the most absolute sense, since it defines the entire realm of possibilities—then, so far as I can see, the above strategy for securing the fact that there could have been different macrosystems stumbles.

Let me sum up this section. I have stated and assessed a proposal to reduce (in section 1 of chapter 3’s sense) the philosophical multiverse to the Everettian one (I restricted myself to chapter 4’s non-cosmological Everettian). I admired the boldness of this proposal. But I cannot believe it. My reasons were not just my belief in the autonomy and generality of logic compared with physics. Also, more specifically: being a Humean, I see the results of science, even results so glorious as those of quantum theory, as both contingent and fallible—so that this proposal gives us an *embarrass de richesse* of necessities.

4. Envoi

One theme has been so prominent throughout this book as to merit a closing quotation. I mean the theme that I derived from Bacon, Locke, and especially Hume: that we should not be beguiled by words, and we should be modest about the kind of understanding of nature that human enquiry—even the glories of modern physics, with their breathtaking quantitative precision—can secure. (See the discussions in section 5 of chapter 1, sections 5 and 6 of chapter 2, and the “Notes and Further Reading” section of chapter 2.)

In Hume’s masterpiece, *An Enquiry Concerning Human Understanding*, he writes near the end of part I of section IV (which is entitled “Sceptical doubts concerning the operations of the understanding”):

Hence, we may discover the reason, why no philosopher, who is rational and modest, has ever pretended to assign the ultimate cause of any natural operation, or to show distinctly the action of that power, which produces any single effect in the universe. It is confessed, that the utmost effort of human reason is, to reduce the principles, productive of natural phenomena, to a greater simplicity, and to resolve the many particular effects into a few general causes, by means of reasonings from analogy, experience, and observation. But as to the causes of these general causes, we should in vain attempt their discovery; nor shall we ever be able to satisfy ourselves, by any particular explication of them. These ultimate springs and principles are totally shut up from human curiosity and enquiry. Elasticity, gravity, cohesion of parts, communication of motion by impulse; these are probably the ultimate causes and principles which we shall ever discover in nature; and we may esteem ourselves sufficiently happy, if, by accurate enquiry and reasoning, we can trace up the particular phenomena to, or near to, these general principles. The most perfect philosophy of the natural kind only staves off our ignorance a little longer: as perhaps the most perfect philosophy of the moral or metaphysical kind serves only to discover larger portions of it. Thus, the observation of human blindness and weakness is the result of all philosophy, and meets us, at every turn, in spite of our endeavours to elude or avoid it.

Wise words. But they imply that deciding what to believe about the various multiverse proposals is hard . . .

So, after this book's relentless, indeed, humourless, dialectical weighing-up of the arguments for and against, it is amusing to see that—if you can forgive the ambiguity of the word “world,” meaning either “planet” or “cosmos”—Alexander the (so-called) Great was similarly daunted. Thus, Plutarch, in section 4 of his “On the Tranquillity of Mind,” writes:

Alexander wept when he heard from Anaxarchus that there were an infinite number of worlds; and his friends asking him if any accident had befallen him, he returns this answer: “Do you not think it a matter of lamentation that when is such a vast multitude of them, we have not yet conquered one?”

Indeed, conquering the multiverse is hard.

5. Notes and Further Reading

I shall give a few suggestions for each of sections 2 to 4 of this chapter. (Section 1, on what I myself believe, referred a good deal to sections in previous chapters, so it needs no further suggestions.) As perhaps befits a final chapter, some of these suggestions will return us to references given in the “Notes and Further Reading” sections of previous chapters.

5.1 Causal Interaction (or Lack Thereof) Between Universes

For section 2, about why we cannot “see” or have causal interaction with other universes, I have two suggestions, both recommended in previous chapters.

The first concerns the use of the double-slit experiment by John Bell in the opening pages of his pedagogic exposition of the interpretations of quantum theory to explain the measurement problem, specifically, the collapse of the wave function to produce the dots (scintillations) forming the interference pattern on the screen. The source is:

- Bell, John. “Six Possible Worlds of Quantum Mechanics.”
As noted in the “Notes and Further Reading” section of

chapter 4, this paper is most easily found in *Foundations of Physics* (1992). It is also reprinted in Bell's collection *Speakable and Unspeakable in Quantum Mechanics* (Cambridge University Press, 1987; revised edition 2004); available at: <https://www.cambridge.org/core/books/speakable-and-unspeakable-in-quantum-mechanics/E0D032E7E7EDEF4E4AD09F458F2D9DB7>

The second is Lewis' masterpiece book-length defence of his modal realism:

- Lewis, David. *On the Plurality of Worlds*. Blackwell, 1986.

This book has two sections that bear directly on the question of why we cannot “see” or have causal interaction with other universes. The first is section 1.6, entitled “Isolation.” (Section 2 of this chapter quotes its closing passage.) The first two-thirds of this section argue that any two objects (across all the worlds) are spatiotemporally related iff (meaning “if and only if”) they are in the same world (in Lewis' terms, iff they are worldmates). And the last third of section 1.6 argues that there can be no causation *a la* Lewis between worlds.

The second relevant section is Lewis' section 1.7, entitled “Concreteness.” This shows in detail that the concrete/abstract distinction is not nearly as clear as many philosophers presume, since it is multiply ambiguous. This is a topic that bears not only on the understanding of causation, but also (as we have seen in section 9.3 and the “Notes and Further Reading” section of chapter 3) on (i) the nature of possible worlds and (ii) M. Tegmark's advocacy of a “Pythagorean” mathematical multiverse.

5.2. Possible Worlds and Everettian Branches

For section 3, which discusses the proposal to identify the philosopher's possible worlds with Everettian branches, the main source is A. Wilson's book-length advocacy of this proposal:

- Wilson, Alastair. *The Nature of Contingency*. Oxford University Press, 2020; available at: <https://global.oup.com/academic/product/the-nature-of-contingency-9780198846215?q=The%20Nature%20of%20Contingency&lang=en&cc=gb>

Several articles preceded the book. Here are three. In the first two, Wilson argues in favour of interpreting the indeterminism of branching in terms of diverging branches/worlds rather than splitting branches/worlds. (Cf. section 3.1's exposition of Wilson's proposal.) In the third, he argues that his proposal accommodates, and indeed supports, the decision-theoretic approach to Everettian probability that I expounded in sections 11 and 12 of chapter 4.

- Wilson, Alastair. "Macroscopic Ontology in Everettian Quantum Mechanics." *The Philosophical Quarterly*, 61 (2011): 363–382.
- Wilson, Alastair. "Everettian Quantum Mechanics without Branching Time." *Synthese* 188 (2012), 67–84; available at: <https://link.springer.com/article/10.1007/s11229-011-0048-9>.
- Wilson, Alastair. "Objective Probability in Everettian Quantum Mechanics." *British Journal of Philosophy of Science*, 64 (2013): 709–737.

Wilson discusses his proposal, as an example of the general idea of naturalizing modality, in his more recent co-authored book:

- Bryant, Amanda, and Alastair Wilson. *Modal Naturalism: Science and the Modal Facts*. Cambridge University Press, 2024; available at: <https://www.cambridge.org/core/elements/abs/modal-naturalism/C44D2B39D91BD577D0E7E59899069275>

As to the literature's responses to the proposal, I recommend:

- The reviews of the book in several philosophy journals, such as *Mind* (Oxford University Press) and *Notre Dame Philosophical Reviews* (University of Notre Dame Press), which is open access and available online only at: <https://ndpr.nd.edu/reviews/archives/>

- Harding, Jacqueline. “Everettian Quantum Mechanics and the Metaphysics of Modality.” *The British Journal for the Philosophy of Science* 72, no. 4 (December 2021), which offers a critical assessment of Wilson’s proposal, together with suggested improvements.

5.3 Physics and Philosophy

For section 4, and thus for the close of the book, it seems appropriate to celebrate the synergy between physics and philosophy—what used to be called “natural philosophy” (as mentioned in section 1 of chapter 2). I will do this by first recalling what I said in chapter 5 about what Eddington really intended with his famous metaphor of the fishing net: namely, to underline the synergy and mutual relevance of physics (or more generally, science) and philosophy. Then, I will close by recommending two articles by Carlo Rovelli.

In the “Notes and Further Reading” section of chapter 5, I quoted the whole passage containing Eddington’s famous metaphor of the fishing net (in his *The Philosophy of Physical Science* (1938)). The net is usually taken to stand for our means of observation in the specific science at hand. In the fishing example, this means the biology of fish, called “ichthyology.” According to Eddington, using a net with a two-inch mesh, we might naively infer that all fish are longer than two inches.

But as I explained, if one reads a little beyond the frequently quoted metaphor, one will realize Eddington takes the net to stand, not just for our means of observation, but also for our scientific method as a whole. Thus, Eddington’s moral is not just the obvious one I stressed in section 8 of chapter 5, viz. “conditionalize your credence on your means of observation,” but also that we should allow for types of knowledge inaccessible to the scientific method. This open-mindedness is bound to be welcome to a philosopher. We should take notice of—and take encouragement from—it.

So, here again is a portion of the latter part of the passage, a portion that makes clear Eddington’s intent. He writes:

An onlooker [i.e., a philosopher savvy about such matters as observation selection effects] may object to [the ichthyologist’s] generalisation [that all fish are longer than two inches]. “There are plenty of sea-creatures under two inches long, only your net is not adapted to catch them.” The ichthyologist

dismisses this objection contemptuously. “Anything uncatchable by my net is *ipso facto* outside the scope of ichthyological knowledge. In short, “what my net can’t catch isn’t fish.” Or—to translate the analogy—“If you are not simply guessing, you are claiming a knowledge of the physical universe discovered in some other way than by the methods of physical science, and admittedly unverifiable by such methods. You are a metaphysician. Bah!”

Finally, here are two articles by Carlo Rovelli, a theoretical physicist with a great gift for philosophy and for work at the interface between physics and philosophy. They are not about the multiverse. Indeed, I think Rovelli would be sceptical of all three of this book’s proposals. But each of them is a manifesto for synergy between physics and philosophy, and so very much in the spirit of this book.

The first declares this in its title, which also gives a salutary message to us philosophers to not be introspective, but to be open to what physics can offer us. An eloquent passage in the second merits being quoted.

- Rovelli, Carlo. “Physics Needs Philosophy. Philosophy Needs Physics.” *Foundations of Physics*, 48 (2018), 481–491; available at: <https://doi.org/10.1007/s10701-018-0167-y>; <https://arxiv.org/abs/1805.10602>
- Rovelli, Carlo. “Halfway Through the Woods,” in *The Cosmos of Science: Essays of Exploration*. University of Pittsburgh Press, 1997. Edited by Earman, John, and John Norton.

The title alludes to the opening lines of Dante’s *Divine Comedy*. Rovelli’s idea is that, like Dante, modern physics is in the middle of a journey, and the path ahead is very unclear. For the quantum and relativity revolutions are by no means settled—there is much still to do. He draws an analogy with the 150 years from Copernicus’ heliocentrism to Newton’s mechanics and theory of gravity (cf. section 3 of chapter 2). In this analogy, the quantum and relativity revolutions are like natural philosophy after Copernicus; and like natural philosophers between Copernicus and Newton—figures like Galileo and Descartes—we ourselves are halfway through the woods, searching for a synthesis of the insights from quantum theory and relativity.

And—happily for us philosophers—he sees this predicament as an opportunity for philosophers. He writes:

General relativity and quantum mechanics are discoveries as extraordinary as the Copernican discovery. I believe they are, like Kepler's ellipses and Descartes's principle of inertia, fragments of a future science. I think that it is time to take them seriously, to try to understand what we have actually learned about the world by discovering relativity and quantum theory, and to find the fruitful questions. Maybe the Newtonian age has been an accident and we will never again reach a synthesis. If so, a major project of natural philosophy has failed. But if a new synthesis is to be reached, I believe that philosophical thinking will be once more one of its ingredients. . . . As a physicist involved in this effort, I wish the philosophers who are interested in the scientific description of the world would not confine themselves to commenting and polishing the present fragmentary physical theories, but would take the risk of trying to look *ahead*.

And after this call to arms, he gives us an uplifting conclusion:

We are not close to the end of physics, nor to the final theory of everything. We are very much in the dark. We left the sunny grasses of Cartesian-Newtonian physics and are traveling through the woods, armed with everything we have learned and with our weak intuition, always wishing we were smarter. It would be a discouraging state of confusion, and we would feel lost, if it weren't that the trip is wonderful and the landscape so breathtaking.