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Are Thought Experiments Just What You Thought?[1]

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I Introduction

Whatever the original intent, the introduction of the term 'thought experiment' has proved to be one of the great public relations coups of science writing. For generations of readers of scientific literature, the term has planted the seed of hope that the fragment of text they have just read is more than mundane. Because it was a thought experiment, does it not tap into that infallible font of all wisdom in empiricist science, the experiment? And because it was conducted in thought, does it not miraculously escape the need for the elaborate laboratories and bloated budgets of experimental science?

These questions in effect pose the *epistemological* problem of thought experiments in the sciences:

> Thought experiments are supposed to give us information about our physical world. From where can this information come?

One enticing response to the problem is to imagine that thought experiments draw from some special source of knowledge of the world that transcends our ordinary epistemic resources. My purpose in this paper,

1 I am grateful to an anonymous referee for many helpful suggestions for improving an earlier draft of this paper.

however, is to argue that thought experiments effect no such epistemic miracles. Insofar as they can tell us about our world, they do so using our standard epistemic resources: ordinary experiences and the inferences we draw from them. That is not to say that thought experiments are unremarkable. They can serve many special and striking functions in science. For example, Jim Lennox has described how thought experiments were used to great effect in evolutionary biology, not to test the truth of a theory, but to test its explanatory potential.[2] His work is part of a recent, explosive growth in the literature on thought experiments in which they are explored from many perspectives.[3] We have much to learn from this literature about the subtleties and diverse functions of thought experiments. My concern here is narrower. I merely urge that thought experiments are *epistemically* unremarkable.

In the next section, in order to develop my thesis, I will sketch two very different viewpoints that have arisen in response to the epistemological problem of thought experiments. One will be my own view that thought experiments are merely picturesque arguments and in no way remarkable epistemologically. I will urge that this view is a consequence of a modest empiricism. The other will be the view of Jim Brown that certain thought experiments afford us a glimpse into a Platonic world populated by the laws of nature themselves. According to my view, it is essential that all thought experiments can be reconstructed as arguments. Brown disputes this. So in Section III, I will consider an array of thought experiments in order to illustrate how they are treated differently by the two views and to demonstrate that each can be reconstructed as an argument. In Section IV, I will state the argument view in more precise form and draw on material from earlier sections to make the case for it. I will recall that the view is a consequence of modest empiricism. I will also argue that the view follows from the fact that it proves possible to reconstruct any thought experiment as an argument. That thought ex-

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2 J.G. Lennox, 'Darwinian Thought Experiments: A Function for Just-So Stories,' in T. Horowitz and G.J. Massey, eds., *Thought Experiments in Science and Philosophy* (Savage, MD: Rowman and Littlefield 1991), 223-45

3 For example, D. Gooding, *Experiment and the Making of Meaning* (Dordrecht: Kluwer 1990); 'What's *Experimental* about Thought Experiments?' in D. Hull, M. Forbes, and K. Okruhlik, eds., *PSA 1992: Proceedings of the 1992 Biennial Meeting of the Philosophy of Science Association*. Volume 2. (East Lansing, MI: Philosophy of Science Association 1993), 280-90; R. Sorensen, *Thought Experiments* (Oxford: Oxford University Press 1992); N. Nersessian, 'In the Theoretician's Laboratory: Thought Experimenting as Mental Modelling,' in Hull, Forbes, and Okruhlik, 291-301; as well as the many papers collected in Horowitz and Massey.

periments can always be so constructed is best explained, I will urge, if thought experiments are nothing more than arguments. In Section V, I will examine a particular aspect of Brown's notion of the Platonic perception of laws. I will urge that it is quite unlike ordinary perception insofar as it obeys no known regularities that would allow us to control misperception. It will follow that the Platonic perception of laws is essentially irrelevant epistemically wherever it transcends argument since its products are only reliable insofar as they can be checked by explicit argumentation.

II Two Views of Thought Experiments

1. Thought Experiments are Arguments

In responding to the epistemological problem of thought experiments, one must decide whether one will regard thought experiments as epistemically ordinary or as epistemically extraordinary. The former is my choice. It derives from a conservative, empiricist philosophy of science according to which all knowledge of our world derives from experience. That is, it holds that scientific knowledge is experience suitably organized and generalized. Empiricist philosophers of science like me must resist all suggestions that one of the principal experiential foundations of science, real experiments, can be replaced by the fantasies of the imagination. This empiricist viewpoint entails that thought experiments are arguments, as I shall now show.

Thought experiments involve no new experimental data. Therefore they can only reorganize or generalize what we already know about the physical world and make it explicit. This prior knowledge rests eventually upon experience and can only enter thought experiments as assumptions, tacit or explicit. Therefore, thought experiments are devices that reorganize or generalize these assumptions to yield the outcome of the thought experiment. That is, these devices are arguments that carry us from our assumptions to a conclusion, the outcome of the thought experiment. Insofar as the device merely reorganizes, it is a deductive argument; insofar as it generalizes in the broadest sense, it is an inductive argument. The outcome is reliable only insofar as our assumptions are true and the inference valid. That is not to say that all thought experiments are instances of perfect deductive or inductive inference. Thought experiments can be bungled, just as arguments can. Rather, when we evaluate thought experiments as epistemological devices, the point is that we should evaluate them as arguments. A good thought experiment is a good argument; a bad thought experiment is a bad argument.

For these reasons, in an earlier paper, I characterized thought experiments as belonging to a subclass of arguments:[4]

> Thought experiments are arguments which:
> (i) posit hypothetical or counterfactual states of affairs, and
> (ii) invoke particulars irrelevant to the generality of the conclusion.

In that paper, I did not devote much attention to the claim that thought experiments are arguments. I believed that position to be rather uncontroversial. Subsequent publication on thought experiments has indicated that my assessment was optimistic and that there is a need for the discussion and defense of the claim which is to follow here. My concern in the earlier paper was the two qualifications (i) and (ii) and their consequences for thought experiments. In brief, the restriction (i) allows for the thought-like character of the argument. Restriction (ii) allows for the experiment-like character of the argument. According to both (i) and (ii), thought experiments employ elements not to be found in the conclusion. I investigated strategies used to expel them from the argument. Further, on my view, these elements are always eliminable without compromising our ability to arrive at the conclusion, although the elimination may make the argument for the conclusion considerably more complicated. The claim that any thought experiment can be replaced by an argument without the character of a thought experiment, I called the 'elimination thesis.'

Note that the view that thought experiments are arguments is not equivalent to empiricism. It is entailed by empiricism, but the converse implication does not obtain. For the converse to obtain, one would need to place restrictions on the character and relationship of the premises. For example, one would have to assume that one cannot generate conclusions with experiential content unless there are premises with as least as much experiential content. Brown has labeled my view as empirical.[5] While there is a natural affinity between empiricism and the argument view, the argument view is logically weaker and correspondingly more secure. In principle, one may hold the argument view with-

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4 J.D. Norton, 'Thought Experiments in Einstein's Work.' Paper presented at The Place of Thought Experiments in Science and Philosophy, Conference, Center for Philosophy of Science, University of Pittsburgh, Pittsburgh, PA, April 18-20, 1986; in Horowitz and Massey, 129-48, on 129. As I indicate in 'Thought Experiments...,' not all arguments satisfying (i) and (ii) are thought experiments.

5 J.R. Brown, *The Laboratory of the Mind: Thought Experiments in the Natural Sciences* (London and New York: Routledge 1991), 46

out any commitments concerning the origin of the premises used in the arguments and their connection with experience.

2. *The Platonic View of Thought Experiments*

What are the alternatives to this type of empiricist epistemology of thought experiments? What are our prospects if we wish to portray thought experiments as epistemically extraordinary? If that wish is serious, then we are obliged to give some sketch of this novel epistemology. Whatever it may be, it cannot be a minor adjustment to the conservative empiricist view. Any alternative must embody an epistemology radically different from the empiricist's, for it must show how we can gain information about the physical world other than through sense experience and inference from it.

Jim Brown has recently developed just such an alternative epistemology in which thought experiments play the most central role. His proposal is developed within several papers and a book.[6] He provides a simple taxonomy of thought experiments.[7] A thought experiment may be 'destructive,' in which case it 'destroys or at least presents serious problems for a theory.' Or it may be 'constructive,' in which case it is 'mediative,' 'conjectural,' or 'direct.' A mediative thought experiment 'facilitates a conclusion drawn from a specific, well-articulated theory.' A conjectural thought experiment 'prod[s] us into conjecturing an explanation for the events experienced in the thought experiment.' Direct thought experiments 'do not *start* from a given well-articulated theory — they *end* with one,' with this resulting theory more than a mere logical development of the suppositions brought to the thought experiment.

The details of this taxonomy have little relevance to the epistemic issues at hand and I will not consider them further.[8] His central epistemological claim pertains to a special class of thought experiment, which

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6 J.R. Brown, 'Thought Experiments Since the Scientific Revolution,' *International Studies in the Philosophy of Science* **1** (1986) 1-14; 'Einstein's Brand of Verificationism,' *International Studies in the Philosophy of Science* **2** (1987) 33-54; 'Thought Experiments: A Platonic Account,' in Horowitz and Massey, 119-28; *Laboratory of the Mind*; 'Why Empiricism Won't Work,' in Hull, Forbes, and Okruhlik, 271-9

7 Quotations are taken from *Laboratory of the Mind*, ch. 2., 34, 36, 40, 41.

8 I have already indicated in a review of *Laboratory of the Mind* that I find this taxonomy arbitrary. See J.D. Norton, 'Seeing the Laws of Nature,' *Metascience* New Series **3** (1993) 33-8 on 36, and J.R. Brown, 'Author's Response,' *Metascience* New Series **3** (1993) 38-40.

are both destructive and constructive at the same time. He calls them 'Platonic' and writes:

> A *Platonic thought experiment* is a single thought experiment which destroys an old or existing theory and simultaneously generates a new one; it is *a priori* in that it is not based on new empirical evidence nor is it merely logically derived from old data; and it is an advance in that the resulting theory is better than the predecessor theory. (77)

The non-empiricist epistemology resides in the special *a priori* character claimed for the outcome of Platonic thought experiments. Following the model of mathematical Platonism, these thought experiments are portrayed as vehicles for perceiving the laws of nature, much as we perceive everyday objects in ordinary sense experience. For, according to Brown's Platonism, these laws have a real existence within a Platonic world, just as everyday objects have a real existence in the world of everyday experience. He writes:

> This *a priori* knowledge is gained by a kind of perception of the relevant laws of nature which are, it is argued, interpreted realistically. Just as the mathematical mind can grasp (some) abstract sets, so the scientific mind can grasp (some of) the abstract entities which are the laws of nature. (Ibid., ix)

Brown finds assurance for his view in the absence of any apparent mediating inference in the emergence of the outcome of the thought experiment. It arises instantly just as ordinary sense experience of an object leads without apparent mediation to the conscious belief in the existence of the object. The absence of apparent mediating inference correspondingly leads him to doubt my argument view.[9] Brown has repeatedly nominated my analysis of thought experiments as antithetical to his own, using this point to launch his own account.[10]

III The Reconstruction of Thought Experiments as Arguments

My purpose in this section is to provide a range of examples of thought experiments to illustrate the difference between the two views. As I work through the thought experiments, I will also take the opportunity to

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9 See, for example, Brown, 'Author's Response,' 38-9.

10 See Brown, 'Why Empiricism Won't Work' and *Laboratory of the Mind*, 46-8, for example.

consider the principal point of divergence between the two views. According to my view, thought experiments are merely arguments, although this character is typically disguised for rhetorical reasons. Therefore, it follows that the workings and achievements of any thought experiment can be revealed and captured fully in an explicit argument which employs the same resources. That is, any thought experiment can be reconstructed explicitly as an argument. In more precise form this claim is:

> *Reconstruction Thesis*: All thought experiments can be reconstructed as arguments based on tacit or explicit assumptions. Belief in the outcome-conclusion of the thought experiment is justified only insofar as the reconstructed argument can justify the conclusion.

Brown, however, holds that many thought experiments cannot be reconstructed as arguments that deliver the same outcome from the same resources. Indeed, the plausibility of his view depends upon this point. For in one of his Platonic thought experiments, the outcome is supposed to arise almost miraculously from an act of Platonic perception quite unlike the mundane operation of ordinary inference. If it turns out — as the reconstruction thesis asserts — that the same outcome can be achieved by ordinary means, we may well begin to wonder if we need the mysteries of Platonic perception to explain thought experiments.

Brown's assault on the reconstruction thesis — indeed, the main thrust of his case against my view — consists in the nomination of a number of thought experiments which he claims cannot be reconstructed as arguments.[11] Although I believe that all of his examples can be reconstructed as arguments, it would be impractical and burdensome to reconstruct every example he mentions. Here I do so for four examples which are representative of the range of thought experiments that Brown discusses.

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11 *Laboratory of the Mind*, 46-8; 'Why Empiricism Won't Work.' Brown also argues in 'Why Empiricism Won't Work' that a goal of a thought experiment can be to produce understanding rather than novel conclusions. He points out that this goal is not incorporated in my account, and he is right. It is not. Yet I do not see that he has established that there is any incompatibility between my account of thought experiments as arguments and the possibility that thought experiments may aid understanding. Indeed, it is the practitioners' lore in the mathematical sciences that one does not really understand this or that corner of some science until one has put sweaty hours into deriving results within it, even if one already knows the results. This is a clear instance of understanding being enhanced by the execution of arguments (derivations) to already known conclusions. To pursue the matter any further would require a more precise notion of 'understanding' than Brown or I have offered.

Brown has also specifically indicated that simple empiricism cannot account fully for any of these four.[12] In each case we will see that the degree of belief conferred by the thought experiment on its outcome coincides with the degree to which the reconstructed argument supports its conclusion. That degree, as with all arguments, is fixed by our degree of belief in the argument's assumptions and the deductive validity or inductive strength of the argument. In these examples, the reader will see the techniques used to carry out the reconstruction. The ease of reconstruction should make plausible that these techniques are sufficient for reconstruction of any thought experiment. Certainly I know of none that can resist them.

1. Galileo's Falling Stones

This ingenious thought experiment has a special place in Brown's account. It provided the inspiration for his view[13] and is the canonical example of a Platonic thought experiment.

In the first day of Galileo's *Dialogues Concerning Two New Sciences*, as a part of a much longer discussion of the vacuum, Galileo's spokesman Salviati seeks to refute Aristotle's view that the speed of fall of bodies is in proportion to their weights and replace it with his own view that all such bodies fall alike. The Aristotelian theory had been stated by the Aristotelian Simplicio. The relevant part is:

> [Aristotle] assumes that moveables differing in heaviness are moved in the same medium with unequal speeds, which maintain to one another the same ratio as their weights. Thus, for example, a moveable ten times as heavy as another, is moved ten times as fast.[14]

Salviati doubts that Aristotle had ever tested the theory with falling stones. Sagredo, the impartial bystander, affirms that his own experimental test had refuted Aristotle's theory. Then comes the dramatic moment. Salviati announces that he can settle the question immediately without experiment and the famous thought experiment is presented:

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12 The fourth example is not actually a thought experiment in the natural sciences. It is a device closely related to thought experiments through which Brown proposes we can perceive mathematical laws of objects of the Platonic realm.

13 *Laboratory of the Mind*, viii

14 Galileo Galilei, *Two New Sciences*, S. Drake, trans. (Madison, WI: University of Wisconsin Press 1974), 65

> But without experiences, by a short and conclusive demonstration, we can prove clearly that it is not true that a heavier moveable is moved more swiftly than another, less heavy, these being of the same material, and in a word, those of which Aristotle speaks. Tell me, Simplicio, whether you assume that for every heavy falling body there is a speed determined by nature such that this cannot be increased or diminished except by using force or opposing some impediment to it....
>
> [Simplicio agrees]
>
> Then if we had two moveables whose natural speeds were unequal, it is evident that were we to connect the slower to the faster, the latter would be partly retarded by the slower, and this would be partly speeded up by the faster....
>
> But if this is so, and if it is also true that a large stone is moved with eight degrees of speed, for example, and a smaller one with four [degrees], then joining both together, their composite will be moved with a speed less than eight degrees. But the two stones joined together make a larger stone than the first one which was moved with eight degrees of speed; therefore this greater stone is moved less swiftly than the lesser one. But this is contrary to your assumption. So you see how, from the supposition that the heavier body is moved more swiftly than the less heavy, I conclude that the heavier move less swiftly. (Ibid., 66-7)

There can be little question that what Galileo gives us here is simply an argument.[15] Insofar as the thought experiment refutes the Aristotelian view, even Brown concedes that we have a straightforward argument.[16] The argument is a *reductio ad absurdum*:

1. Assumption for *reductio* proof: The speed of fall of bodies in a given medium is proportionate to their weights.

2. From 1: If a large stone falls with 8 degrees of speed, a smaller stone half its weight will fall with 4 degrees of speed.

3. Assumption: If a slower falling stone is connected to a faster falling stone, the slower will retard the faster and the faster speed the slower.

4. From 3: If the two stones of 2 are connected, their composite will fall slower than 8 degrees of speed.

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15 Indeed the suggestion is so strong that Salviati's description of the thought experiment as a 'short and conclusive demonstration' (*'breve e concludente dimonstrazione'*) is translated as 'short and conclusive argument' in the H. Crew and A. de Salvio translation (Macmillan 1914; Dover 1954), 62. The non-technical *'dimonstrazione'* can mean the more technical 'argument' but also can mean other means of establishing a result, such as through physical models, so that the translation as 'demonstration' is more literal. I suspect, however, that 'argument' captures the overall intent of the author better. (I thank Peter Machamer for assistance with Italian here.)

16 *Laboratory of the Mind*, 78

5. Assumption: the composite of the two weights has greater weight than the larger.

6. From 1 and 5: The composite will fall faster than 8 degrees.

7. Conclusions 4 and 6 contradict.

8. Therefore, we must reject Assumption 1.

9. Therefore, all stones fall alike.

Now, since Brown agrees that the thought experiment is an argument insofar as it destroys the Aristotelian theory, then he must accept some sort of reconstruction of the thought experiment like the one above, leading up to 8. The Platonic character of the thought experiment must be precipitated by the final transition from 8 to 9. Brown writes repeatedly of this final step: 'The right answer is now plain as day';[17] and 'we grasp it immediately.'[18] The result, Brown claims, comes neither from experience nor from inference from other premises and this is precisely the part of the thought experiment that transcends empiricism.[19] The powerful suggestion is that this is the moment of perception of the Platonic laws.

This final step is actually quite tricky. Its analysis varies according to whether the thought experimenter makes a tacit assumption:

8a. Assumption: The speed of fall of bodies depends only on their weights.

However, in either case, with or without this assumption, it is hard to see any room for a Platonic leap in the final step.

If assumption 8a is made, then the move from the refutation of Aristotle's theory (8) to Galileo's theory (9) is a simple inference. The most general viable theory is that the speed of fall of bodies is some *arbitrary* monotonic increasing function of their weights. (Any other choice would have to allow the function to decrease somewhere, which amounts to the possibility of a heavier body falling slower than a lighter one!) Galileo's own theory arises as the special case of a constant func-

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17 Ibid., 2; 'Thought Experiments: A Platonic Account,' 123

18 'Why Empiricism Won't Work.' See also: 'Galileo's new theory is not logically deduced from old data. Nor is it any kind of logical truth.' 'The transition from Aristotle's to Galileo's theory is not just a case of making the simplest overall adjustment to the old theory' (*Laboratory of the Mind*, 78).

19 'Why Empiricism Won't Work'

tion. Now any admitted function other than Galileo's leads to a contradiction through a simple argument almost exactly the same as the argument steps 1-8 and immediately obvious to anyone who has followed Salviati's inferences. Consider a faster-falling, heavier body and a slower-falling, lighter body. If we connect them in their fall, the slower will retard the faster, so that the composite falls at an intermediate speed. This contradicts the consequence that the heavier composite must fall no slower than either of its lighter parts. Thus we can give the transition from 8 to 9 as

8a. Assumption: The speed of fall of bodies depends *only* on their weights.

8b. Assumption: The speed of fall of bodies is some *arbitrary* monotonic increasing function of their weights.

8c. From 3, 5. If the function is anywhere strictly increasing, then we can find a composite body whose speed of fall is intermediate between the speed of fall of its lighter components.

8d. The consequent of 8c contradicts 8b.

9. From 8d. The function is constant. All stones fall alike.

Where might the Platonic leap reside? First, contrary to Brown's claim, there is *no* question of a Platonic leap being the sole justification of Galileo's theory. The above argument, derived straight from the thought experiment, is a perfectly good justification. The only possibility for the leap lies in the context of discovery. Perhaps the leap lies in the recognition that the *linearity* of the speed dependence is irrelevant to the success of Salviati's refutation, so that Salviati's argument can be trivially generalized to a refutation of any functional dependence that is anywhere strictly increasing. Or perhaps it lies in a supposed power of the thought experiment to prod us to conceive of Galileo's theory for the first time. Conceiving of Galileo's theory for the first time seems to me rather a small achievement, given that one has already made assumption 8a and is now considering just what sorts of functional dependencies are possible. In his fictional dialogue, Galileo certainly attributes no such power to the thought experiment, for Galileo's result is clearly stated by Salviati prior to the thought experiment. In any case, that the thought experiment can prod such a conception seems to me an assumption in psychology that requires experimental test. Neither Brown nor I (nor, for that matter, anyone with even a fragment of exposure to science) would be suitable subjects, since we all learned of Galileo's result in our early schooling. In sum, these possibilities are rather slender threads to support the weight of the Platonic world.

Brown somehow sees the argument steps 1-8 as priming us for a Platonic leap, although it is quite mysterious exactly what in these steps does the priming. In contrast, under my argument view of thought experiments, the steps 1-8 do prime us for the final step from 8 to 9, but now in a way that is not at all mysterious. These steps give us an argument that can be trivially generalized to enable the final step.

The reading of the thought experiment that employs assumption 8a tacitly is the standard reading and the one Brown intends, I think, in his glosses of the thought experiment. This reading is, however, a serious misreading historically of what is actually at issue in the relevant part of Galileo's *Two New Sciences*. For Salviati is in no position to make assumption 8a. The context is the fall of bodies *in media* and Aristotle's view is clearly stated by Simplicio as applying to exactly this case. Modern readers, of course, are usually unable to resist the temptation of dismissing the medium through which these bodies are falling as a confounding distraction that should be idealized away. Are we not really talking about bodies falling in a vacuum and is this not what Galileo's theory is really all about? Perhaps, but at this point in the dialogue, Salviati is in no position to assume away the medium. The broader focus of discussion, the very point that raised the question of falling bodies, is the possibility of the existence of a vacuum. To assume the possibility of a vacuum at this point would be to beg the main question under discussion.

Salviati does assume that the bodies are falling in a medium. He soon allows, for example, that

> one sees gold, which is most heavy, more so than any other material, reduced to a very thin leaf that goes floating through the air, as do rocks crushed into fine dust.[20]

For these cases, assumption 8a is false. The same weight of gold falls differently according to its shape. As a nugget, it falls quickly. As a thin leaf, it falls slowly. The speed of fall of bodies depends also on the shape of the bodies.

Thus, in the event, Salviati's transition from 8 to 9 is rather unsatisfactory, for in the very cases Salviati is considering, Galileo's theory (9) fails to obtain. The transition is marked by an elaborate joust between Salviati and Simplicio. For example, Salviati seems to concede that Galileo's theory does not work exactly but tries to gain an advantage on Simplicio by stressing that Galileo's theory is closer to what actually happens than Aristotle's. Comparing the fall of a one hundred pound iron ball and a

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20 *Two New Sciences*, 69

one pound ball from the height of one hundred braccia, Salviati complains

> You find, on making the experiment, that the larger anticipates the smaller by two inches; that is, when the larger one strikes the ground, the other is two inches behind it. And now you want to hide, behind those two inches, the ninety-nine braccia of Aristotle, and speaking only of my tiny error, remain silent about his enormous one.

In sum, when we place the final step of the thought experiment in its proper context within Galileo's discourse where assumption 8a does not obtain, it does not and cannot give Galileo's theory,[21] so Salviati must devote considerable effort to cover the shortfall. In the argument view, the transition from 8 to 9 is, at worst, a fallacious inference to a falsehood; or, at best, valid only insofar as it is invoked in special cases in which assumption 8a holds, such as the fall of very heavy, compact objects in very rare media. This final step now looks more like a clumsy fudge or a stumble than a leap into the Platonic world of laws.

Whether viewed Platonically or otherwise, our degree of belief in the final outcome of the thought experiment turns out to depend on our degree of belief in the assumption 8a. This dependence illustrates clearly the second sentence in the above statement of the reconstruction thesis. The outcome of the thought experiment is the conclusion 9 of an argument that depends essentially on assumption 8a. Therefore the argument view requires that our degree of belief in the outcome must depend upon our degree of belief in assumption 8a. Insofar as we believe assumption 8a, the thought experiment is strong, as is the corresponding argument; insofar as we doubt assumption 8a, the thought experiment is weak, as is the corresponding argument. This is precisely what the reconstruction thesis requires.

2. *Conjectural and Direct Thought Experiments*

Brown gives a brief exposition of my view and concludes with the claim that it cannot do justice to two of the four types of thought experiments he catalogues.[22] These two are the conjectural and direct thought experi-

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21 Clearly the argument 1-8 can no longer be generalized to yield Galileo's theory. If the slower body is a weight of thin gold leaf fashioned into a parachute, then it will slow the fall of a faster nugget. The composite will fall at some intermediate speed. There is no contradiction since the composite need not fall at the greater speed of a nugget of weight equal to that of the composite, for the two differ in shape.

22 *Laboratory of the Mind*, 46-8

ments. Brown's defining discussion of these two types of thought experiment leaves somewhat unclear how they differ.[23] Both are thought experiments that generate a hypothesis or theory as outcome. The difference seems to be that conjectural thought experiments produce their outcomes with less certainty than the direct thought experiments, for the former produce their outcomes merely as conjectures to explain events discussed in the thought experiment.

Brown does not have convincing grounds for his conclusion that my approach cannot accommodate these two types of thought experiment. The principal reason seems to be that in these cases 'we simply do not have a definite background theory from which we can be said to be arguing to our conclusion.'[24] However, to require that the thought experiment operate only within a definite background theory seems to me to place an unnecessarily restrictive burden on the argument view and I have never required it. To reconstruct a thought experiment as an argument we need only find assumptions. That these assumptions belong to a cleanly articulated theory would simplify the inferences that follow, but it is by no means essential.

Thus, as I have shown,[25] Einstein's thought experiments can employ quite extreme philosophical principles as premises and they prove problematic when made explicit. Further, what I have found attractive about many of Einstein's thought experiments is that they enable him to proceed to important results precisely when there is no stable background theory. Thus Einstein's celebrated elevator thought experiment enabled him to generate the principle of equivalence, his first step to general relativity, in just such a context.[26]

Perhaps Brown intends that the argument view must fail in these cases, since a novel hypothesis cannot be the conclusion of an argument. But this is certainly not the case. Nothing prevents a hypothesis from being the conclusion of an argument and, even though it is in some sense implicit in the premises, it can still be novel in the sense that it was unanticipated. For an example, see my reconstruction of Einstein's elevator thought experiment. Apparently innocent premises lead to a startling conclusion: the principle of equivalence, which will revolutionize our theories of space, time, and gravitation.

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23 Ibid., 40-1

24 Ibid., 47

25 'Thought Experiments in Einstein's Work,' §III

26 I have reconstructed this thought experiment elsewhere; see ibid., §3.2.

Finally, Brown nominates the thought experiments of Newton's bucket and Stevin's inclined plane as examples of the two types of thought experiment that the argument view cannot accommodate.[27] I now show that they can.

3. *Newton's Bucket*

Treatment of this thought experiment is somewhat complicated by Brown's misreading of the thought experiment as a conjectural thought experiment, intended to call upon absolute space as an explanation of puzzling phenomena.[28] It is very clear from Newton's exposition and surrounding discussion in the Scholium to the Definitions of Book 1 of *Principia* that this is not the purpose of the thought experiment. The Scholium is dominated by a single problem: distinguishing the absolute from the relative in the cases of space, time and motion. The absolute are the 'true and mathematical,' whereas the relative are the sensible, the ones we can actually observe. So Newton must repeatedly return to show that the absolutes can be known by some observable effects and can be distinguished from the relative. *That* is the purpose of the bucket experiment. He makes this very clear with the two sentences that introduce the thought experiment.[29]

> The effects which distinguish absolute from relative motion are the forces of receding from the axis of circular motion. For there are no such forces in a circular motion purely relative, but in a true and absolute circular motion, they are greater or less, according to the quantity of the motion.

Similar remarks introduce the closely related two globes thought experiment.

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27 *Laboratory of the Mind*, 48

28 Ibid., 7-10, 40-1

29 I. Newton, *Mathematical Principles of Natural Philosophy*, F. Cajori, trans. (Berkeley: University of California Press 1934), 10. Rob Rynasiewicz has recently argued persuasively that even this meaning misconstrues Newton's true purpose. His goal was not to show that absolute motion can be distinguished observationally from relative motion, but that the meaning of absolute motion is such that it cannot be defined in terms of relative motions. This alternative reading can readily be accommodated in the argument view of thought experiments. 'By their properties, causes and effects: Newton's scholium on time, space, place and motion: The text (Part 1); the context (Part 2).' (*Studies in History and Philosophy of Science* **26** [1995], 133 n.1; 295 n. 2).

The details of Newton's most famous thought experiment are well known. He traces the concavity of the surface of the water in a bucket as the bucket is set in rotation. He finds that this concavity is uncorrelated with the presence or absence of relative rotation between the water and the bucket. It does correlate with the absolute rotation of the water, however. Thus this concavity is an observable effect that can be used to distinguish the absolute rotation of the water from its relative rotation with respect to the bucket. This is plainly an argument, which can be given in capsule form as

1. Assumption: Newton's description of the phenomenon of rotation of a water bucket.[30]

2. From 1: The concavity of the water is not correlated with the relative rotation of the water and bucket.

3. From 1: The concavity of the water is correlated with the absolute rotation of the water.

4. Therefore: The concavity of the water is a sensible effect which distinguishes absolute from relative rotation.

The thought experiment relates to the argument that reconstructs it in just the way the reconstruction thesis requires. Newton's bucket experiment proved not to be as decisive as Newton hoped. For the past century, a tradition of criticism associated with the names of Mach and Einstein have held that the concavity of the water fails to reveal acceleration with respect to absolute space. Rather, all it reveals is acceleration relative to the other masses of the universe.[31] This is reflected in a dubious assumption in the argument. According to the Mach-Einstein analysis, assumption 3 is false. The concavity does not correlate with absolute acceleration but only with acceleration with respect to the other masses of the universe. The success of the argument depends on the degree of belief in assumption 3. The thought experiment is not decisive and this is reflected in a corresponding indecisiveness in the argument.

Finally, if Brown prefers to retain the misreading of the thought experiment as a conjectural thought experiment, he makes no special

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30 Newton does mention that he has actually experienced at least some of the phenomena he describes, so it may not be a thought experiment at all!

31 Einstein is the champion of this alternative reading. Mach's relationship to it proves surprisingly difficult to disentangle. See my 'Mach's Principle before Einstein,' in J. Barbour and H. Pfister, eds., *Mach's Principle: From Newton's Bucket to Quantum Gravity: Einstein Studies, vol. 6* (Boston: Birkhäuser 1995) 9-57.

problems for the argument view. Insofar as there is a clear generation of the hypothesis of absolute space in the thought experiment, then it occurs through a well known inductive inference form, the inference to the best explanation. Absolute space is inferred to as the best explanation of the water's concavity. In this form, the thought experiment seeks to yield a stronger outcome from the same resources. That outcome is now the very existence of absolute space. Before it was merely an observable effect that indicates motion with respect to an absolute space already assumed to exist. This new form is even less secure than the original reading. Presumably Newton agreed for he did forgo the reading that gives the stronger outcome. The precariousness of this new reading is reflected in the argument that reconstructs it. That argument requires an inference from the concavity of assumption 2 above to the hypothesis of absolute space itself. That is a considerable leap since the concavity in question reveals very little of the properties of absolute space that must by hypothesized. For example, its geometry must be Euclidian and it must admit a preferred state of rest. But that is not our concern here. Through these two readings of the thought experiment, once again, we see the reconstruction thesis illustrated. There is a stronger and weaker reading of the thought experiment; the arguments that reconstruct them are of corresponding strength.

4. *Stevin's Inclined Plane*

Stevin's ingenious thought experiment, as revised by Mach and reported by Brown,[32] solves a simple problem in statics. If a mass sits on a frictionless, inclined plane, what portion of its weight is directed parallel to the plane? To answer, we imagine a chain loop draped over a triangular prism ABC as in (I) of Figure 1.

We assume the chain can move without friction. If the distribution of weight of the chain were to lead it to rotate about the prism, then it would do so endlessly, since the distribution of the homogeneous chain about the prism would be unaltered by such rotation. This amounts to perpetual motion, which we assume to be impossible. Therefore, the chain remains at rest in a static equilibrium. Now the hanging loop ADC of the chain acts equally on A and C, since it hangs symmetrically. Therefore it can be eliminated without disturbing the equilibrium to recover (II) of Figure 1 in which the segment AB of the chain must exactly balance the

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32 E. Mach, *Science of Mechanics: A Critical and Historical Account of its Development*, T.J. McCormack, trans. (La Salle, IL: Open Court 1960), 32-4; *Laboratory of the Mind*, 3-6

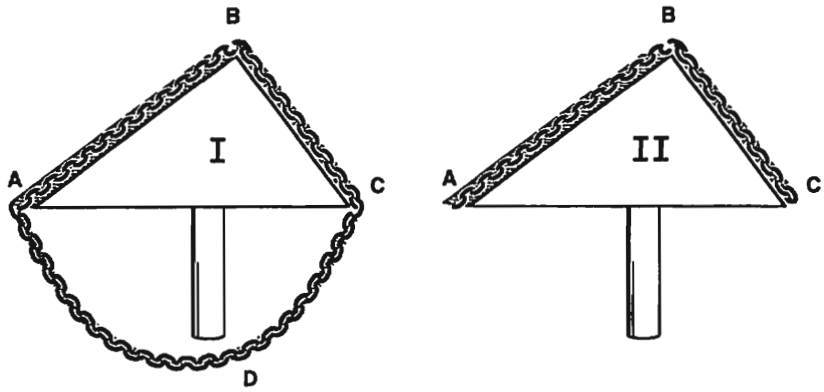

Figure 1 Chain draped over a triangular prism

segment BC of the chain. Since the weights of these segments of chain are proportional to their lengths, we have arrived at what I shall call 'Stevin's result' below:

> On inclined planes of equal heights weights act in the inverse proportion of the lengths of the planes.[33]

This is plainly an argument which is, in capsule form:

1. Assumption: The experimental arrangement is as shown in (I) of Figure 1.
2. Assumption: Perpetual motion is impossible.
3. From 1 and 2: The chain is in static equilibrium.
4. Assumption: Loop ADC hangs symmetrically.
5. From 4: Loop ADC can be excised without disturbing the equilibrium.
6. From 5: Chain segment AB exactly balances chain segment BC.
7. From 1 and 6: Stevin's result.

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33 Mach, *Science of Mechanics*, 34

By any standard, this is an extremely strong thought experiment. Its success was so impressive that it was inscribed on Stevin's tombstone and is still praised today by physicists.[34] As required by the reconstruction thesis, the corresponding argument is equally strong. The argument is deductive. Aside from innocuous assumptions about the experimental arrangements, the only major assumption it requires is the impossibility of a perpetual motion machine, an assumption that has remained unassailed in physics for centuries.

5. A Mathematical Demonstration

Brown routinely uses his mathematical Platonism to support his Platonism in the natural sciences.[35] Mathematical Platonism holds that the entities of mathematics really exist in some realm outside time and space. Since Platonism is most popular in its mathematical form, it gives Brown the least controversial means of introducing the notion of a Platonic realm. Brown continues to propose that we can grasp the realm's contents through certain rapid demonstrations of mathematical theorems. They are not proofs but nonetheless they immediately deliver the theorem and its truth to us. These demonstrations are the analog in mathematics of Platonic thought experiments in the natural sciences. Brown urges that an adequate treatment of these demonstrations lies outside empiricism.[36] An empiricist would have to show that these demonstrations are proofs or arguments and Brown believes they are not.

I do not see the need for me to take a position here on mathematical Platonism. However, my reaction to all of Brown's mathematical demonstrations is univocal. All his examples are simple and very ingenious demonstrations that give us the result sought with wonderful ease and speed. But none is anything more than a simple argument, typically falling short of rigorous proof, and there is no reason to think that any involves a grasping of entities in a Platonic world.

To support my view, I will analyze a representative example that Brown suggests cannot be reconstructed as an argument.[37] The theorem to be proved is in number theory and is

$$1 + 2 + 3 + \ldots + n = n^2/2 + n/2$$

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34 As, for example, by Richard Feynman; see *Laboratory of the Mind*, 6.

35 Ibid., Ch. 3; 'Thought Experiments: A Platonic Account'

36 'Why Empiricism Won't Work'

37 Ibid.

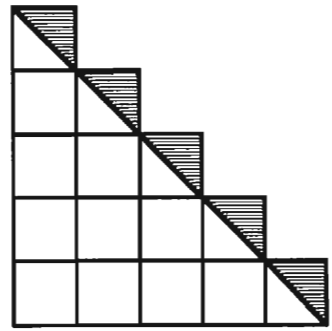

Figure 2 "Proof" of a theorem in number theory

Brown's *entire* 'proof' is Figure 2, which we are enjoined to study to for just a moment to see how it works.

Brown's idea is that we immediately see the truth of the theorem in this figure without supplement of any text and that we do so without elaborate mathematical inferences. The powerful suggestion is that this moment of mathematical revelation coincides with the grasping of a Platonic law.

The trouble with Brown's case is that we do not immediately see the truth of the theorem upon being confronted with the figure. At first we are startled and then we give ourselves a silent commentary on the figure until we work it out. This may take more or less time according to our mathematical abilities but will be rapid in the case of someone with a mathematical background. In my case the silent commentary went something like this, where I have suppressed dead ends and inserted bracketed comments for later reference:

> What has a staircase to do with arithmetic? Is this a joke? Brown is a funny man. Wait a moment. I think I see.
>
> [1. Assumption] Each little square corresponds to an arithmetic unit.
>
> [2. From figure] The figure consists of (n=five) columns of squares of height one, two, ..., (n=five),
>
> [3. From 1 and 2] so that the total number of small squares is the sum we seek, one + two + ... + (n=five).
> But where is the theorem? There has to be some quick trick for getting it from the figure. Oh, I see it. It is easy.
>
> [4. From figure] The total number of squares is the sum of the number of squares in the shaded and unshaded portions.

[5. From figure] The unshaded portion is half of an (n=five) by (n=five) square.

[6. Assumption] An (n=five) by (n=five) square has $(n=five)^2$ unit squares in it.

[7. From 5 and 6] The unshaded portion has $(n=five)^2/2$ unit squares.

[8. From figure] The shaded portion consists of one half square for each column.

[9. From 2 and 8] There are (n=five)/2 shaded squares.

[10. From 4, 7, and 9] The total number of unit squares is $(n=five)^2/2 + (n=five)/2$ which is the result sought.

For most of us, this commentary will proceed very rapidly with many of the assumptions made tacitly. It is *only* after it is completed that we see that the figure does allow a demonstration of the theorem.

It is clear from the way the commentary is laid out that I think it is an argument. Each labeled line is a step. The unlabeled lines are padding. The 'from figure' steps are just another form of premise/assumption. Now this is clearly not a proof in the formal sense, but it is an informal argument good enough to convince all but the sternest skeptics. This is, of course, just what the reconstruction thesis calls for. The thought experiment is convincing; the corresponding argument is informal but strong.

When the 'proof' is dissected in this way, I just see no role for Platonic perception. Each step individually is utterly prosaic. None of the assumptions are controversial. Do we need Platonic perception when we see that one shaded half-square caps each column or when we say that the total number of squares is the sum of the shaded plus unshaded? If so, then Platonic perception is trivialized, for then the simplest of geometric intuitions are Platonic.

The only real candidate for Platonic perception is the generalization from the case of n=5 to the case of arbitrary n. But even here there seems no need to resort to other worlds. It is obvious to anyone with a modicum of mathematical experience that the slots of the commentary-argument that contain '(n=five)' could be replaced by '(n=any number you like).' Each assumption would still stand and each inference step still go through. (Do we need Platonic perception to see that each column is capped by a shaded half square in the [n=seven] case as well?) There is no global leap that might propel us to Platonic heights. Each little step will work for an arbitrarily picked n. So the whole argument works for an arbitrary n.

This discussion embodies a general strategy for analyzing these demonstrations. They are broken down into smaller and smaller parts that are individually trivial but mesh into an argument. We then ask what role there is for Platonism. If it lies in providing the individual parts, then the Platonism is trivialized. If it lies somehow in the totality but not the parts, then the Platonism is irrelevant, since the argument structure by itself is sufficient to synthesize the parts and give the result desired.

IV Thought Experiments are Arguments

Many components of my case for the argument view are distributed in the previous sections. In this section I will draw them together and expand on them to complete the case. First, however, I need to clarify my central thesis. The basic claim of my account of thought experiments is

(1) Thought experiments are arguments.

Brown has pointed out the relevance of the context of discovery/ context of justification distinction to this account.[38] From its statement, it is unclear to which context claim (1) belongs. I do intend both. In each context, (1) can be expressed more precisely as:

(1a) (Context of justification) All thought experiments can be reconstructed as arguments based on tacit or explicit assumptions. Belief in the outcome-conclusion of the thought experiment is justified only insofar as the reconstructed argument can justify the conclusion.

and

(1b) (Context of discovery) The actual conduct of a thought experiment consists of the execution of an argument, although this may not be obvious since the argument may appear only in abbreviated form and with suppressed premises.

Claim (1a) is, of course, familiar to us as the reconstruction thesis.

My own principal grounds for belief in claim (1) is the doctrine of empiricism, which entails the argument view. The argument that takes us from empiricism to this claim was already stated in Section II above. Briefly, according to the empiricist doctrine, all knowledge of the physical world is derived from experience. The outcome of a thought experiment does not rest upon new experience. Therefore, it must rest upon assumptions we have already made and whose justification is decided elsewhere. The transition from these assumptions to the outcome is an argument so that the success of the thought experiment is determined by the validity of the argument.

The case so far has proceeded by descending from the lofty heights of general principle to the claim (1). However, more must be said, for should a thought experiment arise which does not fit the thesis, then it

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38 *Laboratory of the Mind*, 88-90

would constitute a refutation of empiricism by *modus tollens*. Therefore, I also want to show that the case for the argument view can be made in the reverse direction. No general doctrine is assumed. Instead, one ascends from a multiplicity of examples up to claim (1). The first step of this ascent has been carried out in Section III above. The reconstruction thesis — claim (1a) — holds for every thought experiment I have examined, including those specifically nominated by a critic as violating the claim. These are not the only examples. My recent paper[39] contains an analysis and reconstruction as arguments of five representative thought experiments in the areas of thermodynamics, quantum theory, special, and general relativity. They are all drawn from the work of Einstein, one of the greatest of thought experimenters.

Thus claim 1a is subject to a very stringent test. It can be refuted if anyone can find a single thought experiment which cannot be reconstructed as claimed. I am confident this will not happen. The claim in effect advances a challenge: find a thought experiment which cannot be reconstructed as an argument. To my knowledge, no such thought experiment has come to light.[40]

I now turn to claim (1b). At first glance it may seem attractive to accept claim (1a) but not claim (1b).[41] Perhaps logic and argument ought to reign in the pristine context of justification. But in the murky context of discovery, who can say what mysterious processes lead us to our conclusions? Even if we accept claim (1a), why should we want to rule out the possibility that the outcome of a thought experiment is actually produced, for example, by a quick peep into a Platonic world, populated with laws of nature, and that logic and argument only come in later as a device for validating what we saw already by other means? I think there are very good reasons for ruling out exactly such a possibility.

To begin, claim (1b) is not such an implausible claim. Most thought experiments do contain explicit assumptions and at least some explicit argumentation. Is it so implausible to fill in the gaps with tacit assumptions and argumentation? For years, introductory informal logic classes

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39 'Thought Experiments in Einstein's Work'

40 For a historical account of a series of lesser known thought experiments in gravitation theory, see J.D. Norton, 'Einstein and Nordström: Some Lesser Known Thought Experiment in Gravitation,' in J. Earman, M. Janssen, and J.D. Norton, eds., *The Attraction of Gravitation: New Studies in History of General Relativity* (Boston: Birkhäuser 1993) 3-29.

41 From his brief remarks on 83, I take it that Peter Lipton is attracted to this possibility. See P. Lipton, Review of *Thought Experiments in Science and Philosophy*, T. Horowitz and G. J. Massey, eds. *Ratio* New Series 6 (1993) 82-6.

have been taught on the presumption that much of thought is actually tacit argumentation, that it can and should be made explicit and that its soundness can be tested by comparison with known valid and fallacious argument schemes.

However, accepting claim (1a) but not (1b) is unsatisfactory for a stronger reason. It leaves a most striking coincidence unexplained. Thought experiments frequently yield false outcomes. Now it follows immediately from (1a) that the reliability of a thought experiment — its ability to produce a warrantable outcome — coincides exactly with the reliability of an argument. The coincidence is difficult or impossible to explain if we believe that thought experiments are something other than tacit or explicit argumentation. It is completely and naturally explained, however, if we accept claim (1b). To conduct a thought experiment is just to execute an argument. Therefore it can only do what an argument can do. It cannot produce knowledge where an argument cannot. It can only produce such knowledge if an argument can.

The nature of the problem is seen clearly in the parable of Joan. Joan hears voices in the bells and the things the voices say turn out to be true, sometimes. We have no doubt of the honesty and sincerity of Joan, so at first we are inclined to believe that Joan has found a somewhat unreliable oracle in the bells that speaks only to her. However, we soon discover that *every* true prediction that Joan's voices make could have been made by quite prosaic inference from hints and fragments of evidence clearly available to Joan. We also find that the failures coincide with natural misreadings of the evidence. Her voices did correctly predict that the invading army would soon arrive. But then Joan, with her acute sense of hearing, would also have heard the distant rumble of cannon fire, whose ominous significance was unequivocal. Again, Joan's voices predicted that the invading army would be huge. But this time they were wrong. It was quite small. We notice, however, that the army did exaggerate the volume and duration of its cannon barrage precisely to mislead us into believing that the army was huge.

Only the most dogmatic of Joan's followers could deny the significance of this coincidence. The bells are no oracle. They speak only in her imagination. However, Joan does see the implications of the evidence around her and they are the true source of her predictions, although she herself may not be aware of it. And her successes and failures are explained naturally by the success and failure of these inferences.

So it is too with thought experiments, as is summarized in the following consequence:

(2a) Claim (1b) explains why the reliability of thought experiments coincides exactly with the reliability of arguments. In particular, a thought experiment fails for exactly the reasons an argument

> fails: the thought experimenter makes a false assumption or employs a fallacious inference.

Thus to understand the failure of a thought experiment, one need only seek the false assumption or fallacious inference. For example, in Book 1, Section 8, of his *Almagest*, Ptolemy sought to eliminate the possibility that the earth moves. His discussion includes a thought experiment aimed at ruling out translational motion of the earth and the smaller weights upon it:[42]

> if it had some one common movement, the same as that of the other weights, it would clearly leave them all behind because of its much greater magnitude. And the animals and other weights would be left hanging in the air, and the earth would very quickly fall out of the heavens. Merely to conceive such things makes them appear ridiculous.

A similar thought experiment is directed against those who proposed a diurnal rotation of the earth:

> for us to grant these things, they would have to admit that the earth's turning is the swiftest of absolutely all the movements about it because of its making so great a revolution in a short time, so that all those things that were not at rest on the earth would seem to have a movement contrary to it, and never would a cloud be seen to move towards the east nor anything else that flew or was thrown into the air. For the earth would outstrip them in its eastward motion, so that all other bodies would seem to be left behind and to move towards the west.

As every high school physics student now knows, the ridiculous outcomes Ptolemy envisioned do not obtain, because Ptolemy based his thought experiments on a non-inertial physics. Nothing would be left behind by a moving or rotating earth. The principle of inertia would ensure that clouds, projectiles and other objects on the earth's surface would continue to move with the earth, just as though the earth were at rest. The thought experiments fail simply because Ptolemy proceeded from the same false assumption in both cases.

Finally, a straightforward application of Occam's razor speaks for the argument view. The success of the reconstruction thesis shows that the argument view is viable. It is, I urge, also the most parsimonious view of thought experiments. Since argumentation is uncontroversially a part of many thought experiments, any reasonable account of thought experiments must give some place to it. Given that argumentation is also

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42 Translations from M.K. Munitz, ed., *Theories of the Universe* (New York: Free Press 1957), 112

sufficient to provide a complete account of the epistemology of thought experiments, why should we consider calling in any further epistemic machinery? Occam's razor instructs us not to. The magician materializes a dove. We know he can do this by ordinary trickery. Why would we assume that real magic was used?

V Perception of Laws and Ordinary Perception

The preceding section makes the case for the argument view of thought experiments, which is incompatible with Brown's Platonic view. Thought experiments conform exactly to the expectations of the argument view and provide no special comfort for the belief that thought experiments can yield knowledge of the physical world other than through inference from tacit or explicit assumptions. In this section, I will now pursue a quite specific aspect of Brown's case for his Platonism.

As I observed in my review of Brown's *Laboratory of the Mind*,[43] his case repeatedly employs a stratagem based on a supposed analogy between the ordinary perception of everyday objects and the grasping of the Platonic laws. By invoking the analogy, Brown can take an objection against his Platonism and translate it into an analogous objection concerned with the reality of the objects of ordinary perception. Since the latter objection is rarely taken seriously, the original objection is deflected, although not actually answered. The most important application of this stratagem comes in his answer to an extremely vexing problem for his account. Throughout the history of western thought, a priori knowledge has been certain knowledge. Brown now gives us an epistemology in which a priori knowledge is fallible. His defense resorts to the analogy.[44] We are often mistaken in ordinary perception and the inferences make from it, but we do not doubt the reality of the objects of ordinary perception. So why should we be concerned that perception of the Platonic laws is also sometimes mistaken? Those reasons now follow.

If we grant, for argument's sake, that Platonic laws are real and that access can be gained to them through thought experiments, then this access is analogous to ordinary perception in the rather meager sense that information is transmitted from both Platonic laws and objects to us. However, there is a very significant disanalogy in our understanding of the mechanisms which defeats the use of the analogy to mitigate the

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43 'Seeing the Laws of Nature'

44 *Laboratory of the Mind*, 55 and 92-3

fallibility of Platonic perception. The disanalogy is summarized in (3a) and (3b):

(3a) Ordinary perception is well understood insofar as it is governed by an array of familiar regularities. They make the success or failure of ordinary perception controllable and intelligible in all but exceptional cases.

The regularities at issue are those required for everyday functioning. Nearer objects obstruct perception of more distant objects. More distant objects are perceived to be smaller. Without unconscious and routine exploitation of these regularities, our senses would merely deliver falsehoods. We realize the cat has not suddenly dematerialized; our view of it is just temporarily obstructed as it runs behind the sofa. The chair has not suddenly grown; it is only that our vantage point has moved closer to it. We can test the effect at length by repeatedly approaching and receding from the chair. These regularities convert our senses into reliable instruments for investigating the physical world.

We shall see shortly that this rudimentary system for controlling the deliverances of sense perception already far outstrips anything provided for Platonic perception. Of course we do not fully understand every step in the chain from the object sensed to our conscious response.[45] But that is irrelevant to my point. Whatever the process might be it conforms to a host of regularities that allow us to control and gauge its reliability and we routinely do this without understanding anything of the details of the formation of beliefs from sensations. We do this so successfully, that we are rarely aware of it. Only in special cases are we conscious of doing it. For example, we consciously dismiss observation reports of pink elephants when they come from alcoholics and expect LSD to cause hallucinations. More narrowly, optical and aural illusions are catalogued and known sufficiently reliably to be routinely exploited. Designers of clothing are especially adept as this. If you want to look tall and thin, you wear vertical stripes. If you want to look short and fat, you wear horizontal stripes. These examples could be multiplied endlessly.

As it turns out, an understanding of these regularities marks just the beginning of our understanding of ordinary perception. That part of the process that occurs prior to our sense organs is extremely well understood through the laws of optics, acoustics, and other sciences, and we

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45 Our lack of understanding here is stressed by Brown, 'Author's Response,' 39. For the reasons given above, I am also unmoved by Brown's suggestion that the disanalogy between ordinary and Platonic perception somehow depends on attaining a scientific understanding of ordinary perception.

can use this knowledge to understand and correct the vagaries of our perceptions. We see that the distant mountains are blue. But we are not surprised that they are not really blue when we arrive. We understand that distant objects acquire a bluish cast through light scattering. We observe a planet through our cheap telescope and see it is surrounded by rainbows. We know they are not really there since we understand that our telescope has significant chromatic aberration. We see the lightning and hear the thunder several seconds apart. But we know they originated in the same event since we understand that light travels so much faster than sound.

This control and understanding of errors of perception extends seamlessly to the scientific realm, where we routinely correct observation reports by means of our understanding of the mechanism of ordinary perception. We do not doubt that Jupiter has the moons Galileo saw even though we cannot see them with the unaided eye. We know that the human eye is too weak an optical instrument to gather sufficient light and resolve all the moons. Indeed we can compute just how large the eye's pupil would have to be for this task. Conversely, when Galileo[46] reported that Saturn is always flanked by two small stars, one to the east, one to the west, we know we was incorrect. The poor optics of his telescope actually revealed an imperfect image of Saturn with east-west bulges, which he interpreted as flanking stars, rather than the rings our space probe flew past.[47]

Our knowledge of the perception of Platonic laws is rather different:

(3b) The mechanism of perception of Platonic laws is essentially completely mysterious.[48] We have no understanding of why this perception succeeds when it succeeds and fails when it fails.

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46 'History and Demonstrations Concerning Sunspots and Their Phenomena' ('Letters on Sunspots') in *Discoveries and Opinions of Galileo*, S. Drake, trans. (Garden City, NY: Doubleday Anchor 1957), 87-144 on 101

47 Ironically, Galileo condemned others for misreading this imperfect image that 'results from the imperfections of the telescope or the eye of the observer' (101-2). Galileo, however, with his 'excellent instrument,' is sure the bulges are really two stars distinct from the body of Saturn.

48 Since Brown nowhere gives an account of the latter mechanism, I accept his tacit admission in *Laboratory of the Mind* that the process is mysterious (65). He also argues that this should not worry us since the final link from eye to conscious belief of ordinary perception is equally mysterious. I do not accept this defense, since this final link in ordinary perception is controllable by many regularities, unlike Platonic perception.

Thus, when a Platonic thought experiment fails, as Brown allows they can, why we failed to perceive the laws correctly simply remains a mystery. What can the Platonist say to the failure of thought experiments such as Ptolemy's above?[49] Perhaps the best that can be done is to show that a new thought experiment can be advanced that corrects the old. Thus Brown describes a thought experiment of Galileo which corrects thought experiments like Ptolemy's.[50] But such correction does not explain why the original thought experiments failed, which remains mysterious. It simply adds another voice and we must decide which we will hear. The Platonic view gives us no basis for deciding which voice speaks the truth beyond the rather simple and optimistic idea that we may just *know* the truth when we hear it, even though we may well have been mistaken in just such an intuition with the original thought experiment.

Deciding between competing thought experiments remains a serious problem for the Platonist. Brown describes two competing thought experiments.[51] First is the celebrated Newton's bucket, through which Newton sought to establish that rotation with respect to absolute space has observable consequences. It competes with the celebrated Mach-Einstein reanalysis in which these observable consequences are not explained in terms of acceleration with respect to absolute space but with respect to distant matter.[52] The Mach-Einstein reanalysis was the darling of philosophy of space and time for many decades following Einstein's discovery of general relativity. In recent years, however, it has fallen from favor and Newton's original view has been once again become popular. How can the Platonic view explain such shifts of allegiance?

All these worries amount to the failure of Brown's attempt to mitigate the fallibility of Platonic perception by an analogy to ordinary perception. Platonic perception fails routinely. There are no known laws governing its failure. We do not even have the simplest of regularities to call upon. Thus we will never know why it failed when we discover it did or even begin to map out the circumstances conducive to failure. More-

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49 These thought experiments might well be Platonic since they do destroy an older theory (that the earth moves) and simultaneously generate the new one (that the earth is at rest).

50 *Laboratory of the Mind*, 34-46

51 Ibid., 40-1

52 Brown classifies the Newton's bucket thought experiment as a 'conjectural thought experiment.' The Einstein-Mach reanalysis might count as Platonic, since it destroys the older theory (Newton's absolute space) and simultaneously generates a new one (inertia is due to an interaction with distant masses).

over, we can have no confidence that attempts to correct Platonic perception by further perception will fare any better. Were ordinary perception in such a shambles, I doubt we would have any confidence in it at all! To summarize, we now have in contrast with (2a):

(2b) Unlike ordinary perception, the failure of Platonic thought experiments is uncontrollable and cannot be explained or understood even in retrospect.

We have already seen, however, that the argument view of thought experiments has no difficulty accommodating the fallibility of thought experiments. Their failure results from a false assumption or fallacious inference. Again, this view has no difficulty adjudicating between competing thought experiments. Provided both employ valid inferences, we need only look to the assumptions of each to decide which to favor. Thus the adjudication between the Newton's bucket thought experiment and the Mach-Einstein reanalysis is straightforward. I have given an analysis of Einstein's two fluid spheres thought experiment, which embodies the main points of the Mach-Einstein reanalysis.[53] Einstein's thought experiment is seen to rest on at least two rather extreme assumptions, neither of which fits well with recent viewpoints in philosophy of space and time. Thus we have:

(4a) The argument view offers a simple recipe for adjudicating between competing thought experiments.

whereas

(4b) The Platonic account embodies a radical extension of the argument view of thought experiments, but it offers no further mechanism for adjudication between competing thought experiments.

An immediate outcome of the absolute inscrutability of Platonic perception is that it proves to be largely irrelevant epistemically insofar as its results extend beyond the product of simple argumentation. For consider a thought experiment in which we hope Platonic perception of a law has occurred. Is the outcome reliable or a spurious misperception? Did Salviati see clearly when he perceived Galileo's law of fall in the celebrated thought experiment (Section III, 1 above)? As we saw, he did not. The law fails in the special case at hand, the fall of bodies in media. If one thinks only in terms of Platonic perception, the failure remains obscure. Brown himself continues to present this thought experiment as

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53 'Thought Experiments in Einstein's Work,' 139

a paradigm of Platonic perception. As we saw, the failure becomes apparent once we seek to reconstruct the thought experiment as an argument. We have:

(5) The outcome of any supposed act of Platonic perception is incredible insofar as it cannot be validated by reconstruction as explicit argumentation.

At best Platonic perception could function as a kind of hypothesis generator whose products must remain highly suspect until they can be validated by other means.

The mysterious character of Platonic perception has a further consequence. Not all thought experiments are Platonic. In the taxonomy given by Brown, only those that are both destructive and direct count as Platonic.[54] I have been unable to find a rationale in Brown's work for this choice. I presume that part of the difficulty is that we understand so little about the mechanism of Platonic perception that we are unable to decide when it happens and when it does not, let alone its degree of reliability. (This, of course, is quite unlike ordinary perception. We know from the laws of optics that visual perception can only occur in lit environments, that it can be enhanced by optical instruments and that perception through a telescope is more reliable that perception through a kaleidoscope.) However, perhaps we can decide when Platonic perception occurs, even if we are ignorant of its mechanism. Consider a 'mediative thought experiment' which 'facilitates a conclusion drawn from a specific, well-articulated theory.'[55] Since the theory is already in place, perhaps we might presume that no access to the Platonic world of laws is needed.[56] But this type of thinking seems not to help with thought experiments that are destructive or direct but not both. Why are they not Platonic? What faster way of destroying a false theory is there than a simple check of whether that law resides in the Platonic world? Again, how much more directly can we proceed to a theory than to find it within the Platonic world? What mysterious chemistry allows just the inter-

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54 *Laboratory of the Mind*, ch. 2

55 Ibid., 36

56 But how do we rule out the possibility that the closer communing with the laws of just such a peek is exactly what is needed to facilitate the drawing of the conclusion? Again, in the case of a conjectural thought experiment, whose outcome is the conjecturing of a new hypothesis, how can we rule out the possibility that the conjecture was triggered by a glimpse into the Platonic world?

action of the destructive and direct to blast open the door to the Platonic world? To summarize:

(6) Brown gives no account of why just thought experiments that are both destructive and direct are the Platonic thought experiments. In particular, the unintelligibility of Platonic perception makes the possibility of such an account dubious.

To put the point another way, Brown must choose between two impossible options. On the one hand, Brown may allow only very few processes to access the Platonic world. Then he must give us some account of what is special about them and why it gives them such favored powers. On the other, Brown may allow more processes to access the Platonic world. Then we are left wondering why the laws of nature remain so elusive, given that we commune with them so freely.

Finally, the analogy between Platonic perception and ordinary perception, if taken seriously, leads to a further difficulty. Ordinary perception is a real process between a real object and an observer and is governed by physical laws. These laws are real and exist in the Platonic realm. If Platonic perception is analogous it must also be a real process between an observer and the real law and be governed by further laws. Are these meta-level laws also real, existing in the Platonic realm? If so, then we risk triggering an infinite regress. For what of the perception of these meta-laws? Is this perception governed by higher level laws that also are real and exist in the Platonic world? Can we perceive these higher level laws? Each time we repeat these questions and answer affirmatively, we reveal a higher level of laws in the Platonic realm.

We can consider several escapes. Perhaps Brown would like to halt the regress at the first meta-level. He could insist that the perception of laws is not a law governed process. But this would seem to be a betrayal of his Platonism. More weakly, he might allow the meta-level laws to be real, but place them in a higher level Platonic world to which we have no access. This would block the regress. The cost is that he would now have to answer the standard objection to Platonism: what difference does the reality of laws make if we cannot interact with them? For consistency's sake, I cannot see that Brown could accept either escape. Chapter 6 of his *Laboratory of the Mind* drives toward the proposal that the laws of quantum mechanics themselves cause the correlations of an Einstein-Podolsky-Rosen experiment.[57] This would seem to place the interaction of Platonic law and physical objects in the same category as ordinary

57 For a critical analysis of this proposal, see my review 'Seeing the Laws of Nature.'

causation, so that the meta-law that governs it would have to exist side-by-side with the ordinary physical laws resident in the Platonic world.

This last possibility indicates the most attractive escape. We collapse the meta-level into the first level.[58] The laws governing perception of the Platonic world, it might be supposed, reside at the first level of laws and themselves govern the processes used to perceive them. Whether this escape succeeds depends upon a comparison of the processes of perception of ordinary natural laws in the Platonic world and the process of perception of the laws governing this form of perception. If the processes are sufficiently similar to be governed by exactly the same laws, then the regress is blocked. If they require different laws — even only ones that are slightly variant, then we have once again begun our regress by generating more laws.

Does this last escape succeed? We cannot answer and for the same reason that has bedeviled the Platonic account throughout. We understand so little of Platonic perception that we do not even know if there are laws governing it let alone whether the processes that might allow us to perceive them proceed under exactly the same laws as the processes that allow us to perceive other laws. It is only fair to say that none of this amounts to an outright contradiction. Even if a regress is allowed to produce an infinite hierarchy of laws, the Platonist might well just reply, 'And so it is!' However, we do see that the mystery of the perception of Platonic laws is infinitely greater than it first seemed. If a regress to an infinite hierarchy of successively more remote and mysterious laws can be avoided, we cannot avoid the multiplication of unanswered questions.

VI Conclusion

Thought experiments are remarkable. They generate their results with such dramatic ease that there is scarcely a more effective device available to the scientist. Moreover, thought experiments lend themselves to the advancing of particular orientations. I have pointed out elsewhere[59] how Einstein found the vehicle of the thought experiment an especially comfortable medium in which to apply his verificationism. Generations of scientists have stood in awe of Einstein's great achievements and have

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58 This escape was suggested by an anonymous referee of an earlier draft of this paper.

59 In my 'Thought Experiments in Einstein's Work,' §III.

tried to mimic his scientific voice. And when they speak in his voice, they have learned his language of thought experiment. This one example indicates that we have much to learn about how the use of thought experiments has conditioned and directed the development of science.

These broader issues, however, were not my concern in this paper. My concern was the epistemology of thought experiments. I have argued that thought experiments are entirely unremarkable in that narrow arena. They can do no more than can ordinary thinking with its standard tools of assumption and argument. They open no new channels of access to the physical world. Thought experiments are just what you thought.

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