Essays on the Philosophy and Science of René Descartes

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Descartes and Experiment in the Discourse and Essays

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It is generally recognized that knowledge for Descartes is the clear and distinct perception of propositions by the intellect; knowledge in the strictest sense is knowledge by immediate intuition. This means that Descartes was opposed to the idea that true knowledge can be acquired by experience or induction. He believed that knowledge is innate and that it is revealed to the mind through the process of reason. This is why he is so famous for his famous statement, "Cogito, ergo sum," which means "I think, therefore I am."

Descartes believed that knowledge is best attained through the method of doubt. He argued that all our knowledge is based on assumptions and presuppositions, and that these assumptions can be questioned. He suggested that we should start by doubting everything we believe to be true, and then re-examine our beliefs in light of reason. This is why he is often referred to as the "father of modern philosophy."
Descartes’s rule of method has two stages: a reflective step, in which "involved and obscure propositions" are reduced to simpler ones, and a constructive step, in which the newly derived propositions are applied to nature. Décarte’s spiritus is generalizing the examples in a progressive way. 

Descartes’s rule of method was initially illustrated in Rule VIII (see Table 18). The process of reduction is systematically applied to the question of the effect of the sun on the mind. The first question is "Why do we say that the mind is affected by the sun?" (GR, p. 345). In this question, the answer to the second question is "Because the mind is affected by the sun." (GR, p. 345). Descartes’s spiritus is then used to identify the proper answer to the second question. The proper answer is "Because there are some things which are directly affected by the sun." (GR, p. 345). Table 18 illustrates the process of reduction and the proper answers, from the first question to the second question, from the second question to the third question, and so on. 

Table 18: An Example of the Method of Décarte's Spiritus

<table>
<thead>
<tr>
<th>Rule VIII</th>
<th>Question</th>
<th>Proper Answer</th>
</tr>
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<tbody>
<tr>
<td>Q. 1</td>
<td>Why do we say that the mind is affected by the sun?</td>
<td>Because the mind is affected by the sun.</td>
</tr>
<tr>
<td>Q. 2</td>
<td>Because the mind is affected by the sun.</td>
<td>Because there are some things which are directly affected by the sun.</td>
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<tr>
<td>Q. 3</td>
<td></td>
<td>Because there are some things which are directly affected by the sun.</td>
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Descartes’s spiritus is a tool for systematically iterative reduction of questions to simpler ones, until the proper answer is obtained. Once the proper answer is obtained, the question is justified and the knowledge is demonstrated. Descartes spiritus is a powerful tool for understanding the nature of knowledge and the process of justification.
lie at the bottom, and about how it is that we are to find them. In the Rules he seems to take the view that our knowledge of the physical world is grounded in certain truths, immediately grasped, about the nature of bodies, natural powers, and so forth. But in the later writings, the grounding is ultimately in metaphysics, our knowledge of ourselves and God, and in God's role as the guarantor of our clear and distinct perceptions; in the later writings, the intuitions he takes for granted in the Rules must be grounded in God our creator and in us, God's creation. And furthermore, in the latter writings, the reductive step of the method, a step that can lead us only as far as the unjustified intuitions, is abandoned in favor of a direct attack on the foundations. Despite these changes, though, it will be helpful to begin attacking the question of experiment in Descartes by examining the role it plays in his method.

Method and Experiment

In the previous section of this paper I emphasized what might be called the deductive structure of Descartes's project, the view of a completed science as a deduction from initial intuitions. In calling the structure deductive I do not mean to say that it is deductive in precisely the modern sense, or that it is deductive in any precise sense at all. It must be remembered that when Descartes introduces the notion of deduction in the Rules it is in explicit contrast to the formal logic of the schools, indeed, in explicit contrast to any formal procedures at all. For Descartes, intuition and deduction are the immediate grasping of the truth of propositions and the inferential connections between propositions, and so there is no in principle reason why a deduction cannot be an ampliative inference in the modern sense of the term, as, for example, the cogito seems to be. But despite Descartes's refusal to pin down the notion of a deduction in any formal way, a completed science is supposed to be deductive for him in a rather strict sense; derivative and more complex propositions are supposed to be deduced in his sense from propositions more basic and simpler, and grounded ultimately in intuition.

However, Descartes is clear, his natural philosophy is definitely not supposed to be a priori in the modern sense of the term, knowledge obtained without the help of experience. Although Descartes seems to want to proceed deductively, experience and experiment have a significant role to play in this business. It is, of course, well known by now that Descartes was a dedicated experimenter, observer, and dissector, and that the empirical investigation of nature is given significant attention in the Rules, the Discourse, and other writings where he discusses his natural philosophy. Of course, this raises an important problem: how is the appeal to experience consistent with the apparently deductive structure of Descartes's project? There is a considerable literature on this basic question, and answers range from denying (or begrudgingly upholding) the interest in experiment, to denying that Descartes's science was ever intended to be deductive, to claiming that Descartes was simply inconsistent—

deductive in theory, and empirical in practice. This is the problem I would like to address in this section. I shall try to show something that may sound a bit paradoxical, that for Descartes experiment functions as an important and, in fact, indispensable tool for discovery in his deductive science, and it is to experience that we must turn to help us sort out the details of the deductive hierarchy of knowledge.

A reasonable place to begin is with a passage from Part VI of the Discourse, where Descartes attempts to explain to the reader the use of experiment in his thought. The passage begins with a lengthy account of where experiment is not really necessary. Descartes reports that he began his investigations with "the first principles or first causes" of everything, which can be discovered from "certain seeds of truth which are naturally in our souls." From this Descartes derives "the first and most ordinary effects that one can deduce from these causes," the heavens, stars, the earth, water, air, fire, and so on. The passage then continues as follows:

Then when I wanted to descend to theses which were more particular, I was presented with so many different kinds of things that I did not think it was possible for the human mind to distinguish the forms or kinds of bodies which are on the earth from an infinity of others that could have been there, if God had wanted to put them there, nor, consequently, to make them useful to us, unless one proceeded to the causes through their effects, and attended to many particular experiments. Afterward, reviewing in my mind all of the objects which have ever been presented to my senses, I venture to say that I have never noticed anything that I could not easily enough explain by the principles that I have found. But I must also admit that the power of nature is so ample and so vast, and that these principles are so simple and so general, that I have found hardly any particular effect which from the first I did not know could be deduced in many ways, and [I admit] that my greatest difficulty is ordinarily to find in which of these ways it depends on these principles. (AT VI, 64-65)

Experiment seems not to be at issue in the early stages of investigation. Where experiment becomes important, Descartes indicates, is when we move from the very most general features of the world, and, as he puts it, descend to particulars. There, he says, the direct deduction from first principles must stop, and we must "proceed to the causes through their effects, and attend to many particular experiments." This has suggested to many, and not implausibly, that at this stage science must become a posteriori, arguing from effect to cause by a kind of hypothetico-deductive method of the kind practiced in the Essays and defended in the correspondence of 1637 and 1638. While this may describe Descartes's views later, in certain pessimistic sections of the Principles, this is not, I think, what Descartes had in mind in the Discourse. In the passage in question, Descartes seems clear that he is still interested in deduction, even after he has descended to particulars. The problem is that in any given case, there are many possible ways in which one can deduce from the general principles, "so simple and so general," to the particular effects we observe. Experiment is somehow supposed to help us find the right deduc-
tions, the ones that pertain to our world and to the phenomena that concern us. In this way, experiments seem not to replace deductions, but to aid us in making the proper deductions.12

The view is initially quite paradoxical. How can some deductions be right and others wrong? How can it be that experiment is essential for a deductive explanation of a phenomenon? And how could Descartes possibly have maintained a deductive structure in his science, if he admits that there are circumstances in which we must "proceed to causes through their effects"? To see how this might work, let us turn to some examples.

As discussed previously, the anaclastic line problem from Rule VIII involves finding the shape of a surface that refracts all parallel rays into a single point. Descartes's solution to the problem requires us to follow a certain series of steps, first a reduction of the problem to a series of simpler ones, then a constructive step, where the deductive series is traversed backwards, resulting in a deductive solution to the problem, if all works well. Descartes never tells us here where we can or must appeal to experience; experience comes up only in a negative way, where Descartes asserts that we should not try to discover the relation between the angle of incidence and the angle of refraction through experiment, for that would violate Rule III, which tells us that only intuition and deduction are sources of real knowledge (AT X, 368).

But there is at least one place in the reduction where an appeal to experience would seem to be helpful, if not altogether obligatory. In the very next step of the reduction, Descartes says that the investigator must notice that the relation between the angles of incidence and refraction itself depends on the changes in these angles due to the differences in the media through which the ray is passing (e.g., from air into glass, or water into air), and that these changes, in turn, depend on the way in which the ray penetrates the transparent body (AT X, 394). Descartes does not mention experiment or experience in this context. But it is difficult to imagine that this is a step that we can make on the basis of the "seeds of truth" alone. While it may not require sophisticated optical experiments, it seems that we at least require some minimal experience with light rays and lenses, or other actual instances of refraction, in order to see that light is typically bent by passing from one medium into another, and to come to the realization that in order to discover the law refraction obeys we must first understand how light passes through media of different sorts. In this way experience would seem to help us to see how we might proceed in our investigation by suggesting what further questions it might be useful for us to look into.

Experiment comes up at best only implicitly in the anaclastic line example. But it is quite a visible feature of another example Descartes gives of his method. The example I have in mind is the account Descartes gives of the rainbow in the Eighth Discourse of his Meteorology. This passage contains the only explicit mention of the method in all of the Essays, and it is singled out in a letter from 1638 as an exemplary use of the method in practice (See AT VI, 325; Ofs 332 and Descartes to Tart, 22 February 1638: AT 1, 559; CSMK, 85). The example is a very complicated one, one of Descartes's best but most

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Figure 18.1

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complex scientific arguments. I shall begin by summarizing the argument, and then try to show how the mass of experimental detail and complex argument sorts itself out into a methodical framework (see Fig. 18.1). The problem is to explain how it is that rainbows come about. The account begins with the observation that rainbows appear when and only when there are water droplets in the air. Descartes then turns to the study of large spherical flasks of water which, he claims, duplicate the effects seen in individual droplets of water that appear to cause the rainbow. Observations on the flask allow Descartes to measure the angles at which colors are observed, and allow him to determine that there are two regions of color whose red portions are about 42 and 52 degrees from the angle at which they are hit by the rays of the sun (see Fig. 18.1). These experiments also allow Descartes to determine that these two regions of color derive from two different combinations of reflection and refraction within the water flask; the brighter color region (which corresponds to what is now called the primary bow) at 42 degrees results from two refractions and one internal reflection, while the dimmer color region (the secondary bow) at 52 degrees results from two refractions and two internal reflections. (The two paths can be discerned within the flask represented in Fig. 18.1). These investigations lead Descartes to two further questions,
why there is color at all in these cases, and why it is that the colors appear at two specific angles. The first question, that of color, is explored experimen-
tally, through a prism, in which, like the flask, colors are produced through
the reflection and refraction of light (see Fig. 18.2). Observations made with
the prism show that a curved surface, like that of the raindrop or the flask, is
not needed to produce color; nor is a reflection necessary. Descartes discovers
through experiment. What seems to be necessary, Descartes finds, is at least
one refraction, and a restricted stream of light. But in order to understand
how the refraction of a restricted beam of light can produce color, we must
press deeper into the nature of light and the way it passes through a transpar-
cent body, the very questions that we were pressed back into is the anaelastic
line case. The nature of light we know from the **Dioptrics**: "[The nature of
light is] the action of movement of a certain very fine material whose particles
must be pictured as small balls rolling in the pores of earthly bodies" (AT VI,
331; OIs 336). And, Descartes argues, what happens when a restricted beam
of light passes from one medium into another in refraction is that the balls are
given differential tendencies to rotate, depending on where they are in the
stream (see Figs. 18.2 and 18.3). Since, refraction aside, that is the only
mechanical effect that passing from one medium into another has on the light,
Descartes argues that color just must be caused by the differential tendency to
rotation. Those balls with a greater tendency to rotate produce the color red
in us, Descartes claims, while those that have a lesser tendency to rotate
produce the color blue/violet in us. (Remember, of course, Descartes held
that in the strictest sense, color is only in the mind, and not in bodies.) And
so, from the nature of light and the way it passes through media, we have
shown how colors are produced. Descartes thinks. But it still remains to show
why the colors are produced in two discrete regions, at characteristic angles
from that of sunlight. To solve that problem, Descartes turns back to the flask.
Appealing to the law of refraction, which Descartes alludes to in the ana-
elastic line example, and derives (after a fashion) in the Second Discourse of
the **Dioptrics**, he demonstrates that after two refractions and one reflection,
the vast majority of a bundle of parallel rays hitting the flask, wherever they
may hit, will emerge from the flask between 41 and 42 degrees with respect to
the angle of the incident light, and after two refractions and two reflections, the majority will emerge at between 51 and 52 degrees (A": VI, 336ff.; Ols 339ff.). From this it follows that at those two regions on the surface of the sphere, there will be two discrete streams of light that emerge from the flask, moving from one medium into another. And from the previous argument, this will result in two regions of color at the two angles earlier observed. And so, from the nature of light, the way it passes through media, and the law of refraction, it follows that the rays of sunlight hitting the flask will result in two regions of color at two characteristic angles. When we have a multitude of such drops, we have a rainbow.

It is by no means obvious how this somewhat confused mass of experiment and reasoning can be fitted into the rather rigid mold of Descartes’s method. The schematic representation of the argument given in Table 18.2 indicates one plausible way in which the argument might fit. In the schematic representation of the argument, Q1 through Q5 represent the reduction, which leads us from the question originally posed, “what is the cause of the rainbow,” back to the intuitions which are the starting point of the Cartesian deduction, intuitions about the nature of light and how it passes through media. But the important thing is, of course, the specific path that Descartes follows, which he will take to the initial question to the intuition, for it is that path that will determine the path followed in the deduction. In this case Descartes proceeds by splitting the question into two questions, one about color and one about the two regions. Included in square brackets are the empirical results derived from experiment at the point in the argument in which Descartes appeals to them. The path followed after the intuition is relatively straightforward. Here we are dealing with the same steps followed in the reduction, only in the reverse order, as we pass from intuition to the final answer to the question originally posed. But unlike the reduction, experiment and its results seem to play no role in this part of the argument. The example is certainly much more complex than the anelastic line example, but it seems to have much in common with it in structure.

Before turning back to my main theme, the use of experiment in these arguments, I would like to comment on the kind of deduction that is involved in this case. In the anelastic line case, we had a definite question, the shape of a lens with such-and-such properties, and at the conclusion of the procedure we can expect a deductive answer to the question, a deduction from basic principles (ultimately, the nature of a natural power) that a lens with this or that shape will have such-and-such characteristics. But the situation here is a bit different. What we are seeking is the cause of the rainbow. The answer to this question is, in a sense, not deduced; rather, it is revealed in the deduction itself. The deduction shows us how we can go from the nature of light to the phenomenon of the rainbow; what is deduced, strictly speaking, is just the phenomenon itself, the patches of color in the sky. But the path followed in deducing the phenomenon shows us that the cause is the passing of light from one medium to another, the differential tendency to rotate this passage gives the particles of light, and the way that the law of refraction causes light rays to converge into two discrete streams at two characteristic angles. This is a deduction, but a deduction of a very different sort than the one in the anelastic line example. One can quite plausibly ask if Descartes can really be sure that he has given the true sequence of causes that produce the rainbow, as opposed to
a possible sequence that produced the same appearances. Descartes himself will later come to see that as a problem. But in the *Meteorology* it is not; he seems confident that the methodological procedure of investigation he is following assures him that he has captured the real causes.

To return to my own thread, a number of interesting things emerge from these two examples. First of all, it would appear that experiment functions strictly at the reductive stage of method, the stage in which we are trying to go from a question posed to the intuition from which the answer is to be derived; experiment seems not to be involved in the actual deduction. And in that initial stage of inquiry, it seems to function in two not altogether separable roles. First of all, it helps better define the phenomenon to be deduced or the problem to be solved. This is not at issue in the anachronic line example, where the problem is set with sufficient precision. But it is an important function of experiment in the rainbow example, where Descartes appeals to experiment to fix what the rainbow is, that it consists of two separate bows, and that the two bows are always at such-and-such an angle with respect to the rays of the sun; in this way, experiment clarifies the question that is to be answered. But just as importantly, experiment aids the reduction by suggesting how things depend on one another, and that was, in a way, what the question we might turn to next. It is because we know from experiment that refraction depends on a light ray passing from one medium to another that we know that we must investigate light rays, media, and how light passes through a medium in order to determine the law of refraction. Similarly, it is because of experiments with the prism that we know that reflection is irrelevant to color, but refraction is not, and it is because we know that colors can arise from the refraction of light that we know that the nature of color is to be sought in an examination of what light is, and how it is altered by refraction. Once we understand Descartes’s method and the roles that experiment does (and does not) play in it, it should come as no surprise that Descartes might suggest that “it would be very useful if some person were to write the history of celestial phenomena in accordance with the Baconian method . . . without any arguments or hypotheses” (Descartes to Mersenne, 10 May 1632; AT 1, 251; CSMK, 38). The sorts of tables that Bacon recommends to the investigator in Book II of his *Novum Organum* can tell us, for instance, that factor A (color, say) is always accompanied by factor B (refraction, say), but the factor C (say reflection) is present in some cases but absent in others. In an investigation of A, this could lead us to questions about B, and prevent us from raising irrelevant questions about C, as when in the rainbow example we learn that reflection is relevant to color, but refraction is not. Such tables of phenomena and their correlations with one another, independent of any theory, are precisely what Descartes needs to define problems and to determine the relations of dependence of one phenomenon on another necessary to perform the reductive step of the method.

In this way, it seems to me that experiment is not a replacement for deduction, but part of the step preliminary to making a deduction. Science remains deductive for Descartes; in the end our knowledge of the cause of the rainbow depends on our performing a deduction of the phenomena from an initial intuition. But experiment seems to play its role in preparing the deduction. Insofar as it helps perform the reductive part of the method, the sequence of steps that leads from a question to an intuition, it helps determine the deduction, the same steps followed in reverse order that leads from intuition to the answer to the question posed. The deductive chain that the Cartesian scientist seeks in reason, the chain that goes from more basic to less, is exemplified in the connections one finds in nature itself. Insofar as these latter connections are open to experimental determination, we can use experiment to sketch out the chain of connections in nature and find out what depends on what, and thus we can use the connections we find in nature as a guide to the connections we seek in reason. It may not be obvious to us at first just how we can go deductively from the nature of light to the rainbow, but poking about with water droplets, flasks, and prisms may suggest a path our deduction might follow.

This understanding of how experiment and observation may be useful in a deductive science of the sort that Descartes was attempting to construct allows us to make some sense of some of the more puzzling aspects of Descartes’s remarks. On this understanding, we do find causes through their effects, in a sense; experiment is quite necessary in solving problems and helping us to discover the real causes of phenomena in our world. But in no sense are we replacing deductive with a posteriori reasoning. Though we must appeal to experiment, experiment only prepares the deduction that will establish the cause. Furthermore, we can now see how experiment can point the way to the “correct” deduction, and eliminate the “incorrect” deductions. There can be alternative derivations of a given phenomenon in the sense that the same bare effect may be produced by different chains of causes. For example, a distribution of colors in a pair of bows in the sky (a bare effect) may be produced by the reflection and refraction of light through raindrops (as it actually is in our world), or by a distribution of colors resulting from the diffusion of light through ice crystals (as it actually is in our world), or by a distribution of colors projected by a slide projector on a cloud of dust, or by any number of other perversely mean means. But experiment helps us find the correct deduction, that is, the correct chain of causes, by making the phenomenon more precise, and suggesting how it is that the phenomenon is actually produced in this world. In this way experiment can lead us to the correct derivation, correct in the sense that it represents the way the phenomena are caused in our part of the universe. Alternative deductions are not wrong, strictly speaking; one might be able to produce something that looks to us very much like a rainbow in any number of ways. But it’s just that it is not the way things are done here, at least not the way it is done in nature.

So far I have talked about experiment in the context of Descartes’s official method. But, as I pointed out at the very beginning of this essay, I think that Descartes later came to set his method aside. In his later writings, those that follow the Discourse, I would argue that Descartes abandoned the reductive stage of his method in favor of a direct attack on the tree of knowledge, starting from intuition (or, rather, first principles, first philosophy) and deduc-
Experiment and the Priority of Reason

In the previous section, I tried to show how experiment plays a role in Descartes's scientific procedure, and how experiment is preceded by certain judgments and conclusions that are made on the basis of intuitive knowledge and self-evident truths. But I wanted to show that in Descartes's method of reasoning, the distinction between the intuitive and the experimental is not so clear-cut as it is in the case of the philosopher who relies on the distinction of the senses. In the case of Descartes, the senses are not as clear-cut as they are in the case of the philosopher or the scientist, who relies on the distinction between the intuitive and the experimental.

In his discussion of the senses, Descartes is careful to distinguish between the senses and the judgments that are made on the basis of the senses. He argues that the senses are not as clear-cut as they are in the case of the philosopher or the scientist, who relies on the distinction between the intuitive and the experimental. Descartes argues that the senses are not as clear-cut as they are in the case of the philosopher or the scientist, who relies on the distinction between the intuitive and the experimental.

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Descartes states that sensation, the indication to believe that something exists, is a source of knowledge. However, he does not equate sensation with knowledge, but rather as a source that can be doubted. The principle idea is that a thing is considered to be true when it is sensed, but it can be doubted. This is an example of the foundationalist's view, which states that foundational beliefs are self-evident and can be doubted directly.

Descartes believes that the existence of God can be proved through the argument that we cannot doubt our own existence. If we cannot doubt our own existence, then we must be existing beings, and it is reasonable to assume that we exist because we think. This leads to the conclusion that there must be a being who exists and who created us.

Descartes uses the example of the rainbow to illustrate his argument. We can see the rainbow without doubt, yet we doubt whether it is real or not. This is because we cannot be certain that what we see is not a mirage or some other illusion. This leads to the conclusion that we cannot be certain of what we see, even though we see it.

Descartes also argues that the sensation of color is not caused by the object itself, but by the light that reflects off the object and enters our eyes. This means that the sensation of color is not a reliable indicator of the object's existence. This is because we can see colors even when the object is not present, and we can see the object even when it is not colored.

Descartes concludes that sensation is not a reliable indicator of knowledge, and that we must rely on reason to establish knowledge. He argues that the only thing we can be certain of is our own existence, and that this is sufficient to establish the existence of God. Therefore, we must rely on reason to establish knowledge, rather than on sensation.
or, perhaps, to guide us to that theory. In this sense, observation would seem to be a-theoretical for Descartes. But at the same time it is extremely important to realize that the observations Descartes presents as motivating his account of the rainbow, or at least guiding it, are not to be trusted fully until we have an account of the matter, until we can derive those observations from more basic principles. There is such a thing as pre-theoretical observation for Descartes, and this does seem to have a role to play in his procedure. But, at the same time, there is an important sense in which observation does not attain the status of fact until it becomes integrated with theory, indeed, until it becomes subordinated to theory.

In this way, for Descartes, experiment by itself can establish no facts; while experiment can lead us to facts, it is only the final deduction of a phenomenon from intuited first principles that establishes the credentials of a fact, even if first "discovered" through experiment. In his recent writings, Ian Hacking argues that experiment must be viewed as in an important sense independent of theorization in science; "experiment has a life of its own which it insists." By this he means to point out, among other things, that experiment does not function exclusively in the service of theoretical argument, furnishing premises for theoretical arguments, testing theories proposed, allowing us to eliminate one of a pair of competing theories and accept another, and so forth. This may be true enough for a wide variety of figures. But it is not true for Descartes. For Descartes, at least in the context of the rainbow, experiment plays a carefully regimented role in what is from the start a theoretical project. But, at the same time, neither do experimental phenomena have a role assigned to them in standard hypothetico-deductive conceptions of scientific method, as the touchstone of theory, the a-theoretical facts to which we can appeal to adjudicate between alternative theories. If my account of experiment is correct, then however much experiment might help us to find the correct account, it is ultimately reason, not experiment, that is the touchstone of reality, for theory as well as for the experimental facts that help us construct theories.

On the standard view of things, widely shared since the late eighteenth century or so, there are two sorts of philosophers: rationalists and empiricists. Descartes is traditionally viewed as a rationalist, in fact, the founder of the school, in modern times at least. When the extent of Descartes's dependence on experiment and observation is recognized, there is a temptation simply to think that Descartes must have been placed in the wrong slot, and conclude that he must really be some sort of empiricist. I would resist that temptation. It seems to me that what the case of Descartes shows is how crude the scheme of classification really is. For Descartes both reason and experience are important, though in different ways. His genius was in seeing how experience and experiment might play a role in acquiring knowledge without undermining the commitment to a picture of knowledge that had motivated him since his youth, a picture of a grand system of certain knowledge, grounded in the intuitive apprehension of first principles.

Other than the abbreviations used throughout this book (AT, CSM, CSMK, HB), when quoting Meteorology or the Discourse I use the following abbreviation.


2. To avoid confusion, I should point out that I am breaking with most commentators, who refer to these as the analytic and synthetic steps, following the distinction Descartes draws in the Second Replies: AT VII, 125–56 or AT IX, 121–22. See, for example, C.纳斯, La methode de Descartes et son application a la methypsique (Paris: Librairie Felix Alcan, 1933), ch. 1; L. J. Beck, The Method of Descartes: A Study of the Regulae (Oxford: Oxford University Press, 1952), ch. 11, etc. This is a distinction that has little direct relevance to the stages of the method of the Rules. In the Rules we are dealing with a distinction between two parts of a single method; though they are distinct, both are necessary for a true application of the method. But the distinction between analysis and synthesis in the Second Replies is completely different. These we are dealing with different ways of setting out a single line of argumentation, and we must choose one or the other. On analysis and synthesis see also D. Garber and L. Cohen, "A Point of Order: Analysis, Synthesis, and Descartes' Principles," Archiv fur Geschichte der Philosophie 64 (1982): 136–147.

3. Rule IX tells us that in order to understand the notion of a natural power, "I will reflect on the local motions of bodies" (AT X, 402). What this suggests is that the understanding of illumination is, somehow, an intuitive judgment about the simple nature, motion, though it is not clear exactly how he thought this would work.

4. Descartes writes, "If, at the second step, he be unable to discern at once what the nature of light's action is... he will make an enumeration of all the other natural powers, in the hope that a knowledge of some other natural power will help him understand this one, if only by analogy" (AT X, 395). In personal correspondence John Nicholas has emphasized to me the importance (and complexity) of this step in the construction. He suggests, plausibly, I think, that "human limitations are such that in practice we commonly cannot carry out the downward deduction, and have to fall back on the surrogate step of analogizing and comparing with other natural agencies than the targeted one." Insola: as this analogizing may depend on our experience with the phenomenon in question, as well as with other phenomena, this suggests to him that there may be another use of experience in Descartes than one that I emphasize in the following sections. He might well be right.

5. See Pierre Costabel, 'Genres originaux de Descartes savant' (Paris: Vrin, 1982), 53–58, for an account of the historical background to this example.

6. See especially the development in Rule XII (AT X, 419) where Descartes discusses the so-called simple natures on which all of our knowledge is supposed to be grounded. The simple natures divide into three classes: intellectual, material, and common. The intellectual simple natures include knowledge, doubt, ignorance, volition. The material simple natures include shape, extension, and motion. The common simple natures include existence, unity, and duration.
7. For a fuller account of the changes, see n. 1 in this essay.
tion" is so broad for Descartes that even hypothetical arguments count as deduc-
9. For a survey of the various views taken in the literature, see Clarke, Descartes' Philosophy of Science, 9–10.
11. One might point here to the obvious use of hypotheses in the Dioptrics and Meteorology, well before the Principles of Philosophy; see AT VI, 383f., 233f.; Ols 76f. (264f.). But the Essay consists on an investigation that gives the results of inquiry without revealing the full system, and they are not intended to replace proper argument in natural philosophy, which proceeds from cause to effect. By arguing from hypotheses he thought that he could show some of his results without having to divulge the basic
principles of his physics, for which, he believed, the public was not ready. But, while pleased with his Essay, he was clear that they represent not the definitive treatment of his thought, in accordance with his method of inquiry, but, rather, interesting experi-
ments in exposition. There is an extended discussion of this in Part VI of the Dis-
course: AT VI, 76–77. This theme also runs through Descartes's correspondence in the period; see AT I, 562–594; AT II, 141–144, 199–200; CSMK, 87–98, 103–104, 107.
See also Garber, "Science and Certainty in Descartes" and Descartes' Metaphysical
Physics, ch. 2.
12. See also Descartes' remarks in Principles III, a. 4. There he talks about having to turn to the phenomena at that stage in his exposition, "not to deduce an account of causes from their effects," but "to direct our mind to a consideration of some effects rather than others from among the countless effects which we take to be producible from the selfsame causes."
13. My own interest in the rainbow case here is largely as an illustration of the method of the Rules. For discussions of Descartes's account of the rainbow that empha-
Descartes et sa méthode, 145–162. Considering Descartes's account in his historical perspective makes it quite clear that despite the impression he gives in the Meteorology of having discovered everything himself, he owes a great deal to previous investigators. Interesting and important as these historical considerations are, I will focus instead on Descartes's presentation of his theory in an attempt to untangle the methodological undertones of his argument.
14. This is the paraphrase Descartes gives in the Meteorology; the passage he is referring to in the Dioptrics can be found at AT VI, 89–93.
15. Descartes does the calculation by considering a spherical droplet of water hit by parallel rays over one hemisphere, and calculating where various of the rays would emerge after an appropriate number of reflections and refractions. His conclusion, carefully stated, reads:

I found that after one reflection and two refractions, very many more of the rays can be seen under the angle of 41 to 42 degrees than under any lesser one; and that none of them can be seen under a larger angle. Then I also found that after two reflections and two refractions, very many more of them come toward the eye under a 51 to 52 degree angle, than under any larger one; and no such rays come under a lesser. (AT VI, 356; Ols, 390)

While the conclusion is arrived at by calculation, that calculation must make explicit appeal to the index of refraction for water. When the question comes up in the Second Discourse of the Dioptrics, he notes that we must appeal to experience in order to determine the value of this constant for various sorts of materials (AT VI, 101–102). This would seem to be ano/his place in which experiment would enter into the
method. However, one presumes that Descartes believed that the index of refraction could itself be arrived at by calculation, were we to know the size, shape, and motion of the corpuscles that make up water.
16. See, for example, Descartes's remarks in Principles IV, 204–206; see the discus-
sion of these passages in Garber, "Science and Certainty in Descartes."
17. See the discussion in Rule XIII, AT X, 430–431, where Descartes discusses the importance of specifying in exact terms what is being sought in an investigation.
18. See Descartes, La destruction du corps humain, AT XI, 252f.
19. For a development of some of these themes in Descartes, see Garber, "Somel
20. For a fuller presentation of this argument, see ibid.
21. In the version of the argument given in Principles II, a. 1, Descartes does seem to argue from the fact that "we seem clearly to see" that sensation proceeds to us from the object of our idea of body is the real existence of body, and does not appeal to the "great propensity" that is the hub of the argument in the Meditations. It is not clear why the later text differs from he earlier one on this point. It may represent a genuine change in Descartes's epistemology. But then it may simply reflect Descartes's desire not to enter into his full account of the senses in the Principles. For the relation between the Meditations and the Principles, see Garber and Cohen, "A Point of
Order."
22. That is, we can trust at least some of the judgments that characteristically accompany our sense perceptions. What seems to be at issue here is the third of Descartes's three grades of sensation; see AT VII, 436–437.
23. For a discussion of Maurolycus's theory of the rainbow, see Boyer, The
Rainbow, 156–163. The implication of Descartes's remarks is that Maurolycus's theories for the angles derive from observation alone. This is not entirely fair. Maurolycus had his reasons for seeing the angles as he did, reasons based on his (incorrect) analysis of the path the light follows within the raindrop; indeed, he knew that his calculated value differs from what was known through observation, something for which he attempted to offer an explanation (pp. 138–166).
24. We must, of course, remember that the calculation does appeal to an experi-
mentally determined value for the index of refraction; however, as I pointed out earlier, Descartes would surely have thought that a "reason" could be given for that also.
25. Ian Hacking, Representing and Intervening (Cambridge: Cambridge Univer-
sity Press, 1983), 150.
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26. Descartes does say some things that would appear to go against my conclusion. For example, immediately following the long passage from Part VI of the Discourse I quoted earlier, Descartes writes,

I know of no other means to discover this [i.e., how a particular effect depends on the general principles of nature] than by seeking further experiments [expériences] whose outcomes vary according to which of these ways provides the correct explanation. (AT VI, 65)

But, I think, this must be understood in the context of the interpretation I have offered earlier. The experiments in question must be viewed as leading us down one deductive path rather than down another, and not as a theory-neutral means of choosing between independently constructed theories; for, as Descartes elsewhere insists, we cannot really be sure of an experimental fact until after we have already determined what the correct deduction is.

27. See, e.g., Clarke, Descartes’ Philosophy of Science, 205.

28. In addition to its presentation at the San José Descartes Conference, earlier versions of this paper were given in University of Rochester, University of Colorado. Columbia University, Catholic University of America, University of Notre Dame, Georgia Philosophical Association, University of California at San Diego, Virginia Polytechnic Institute and State University, University of Illinois, and the University of Ohio. I would like to thank the audiences there, as well as Peter Dear, Ernan McMullin, John Nicholas, Gary Hatfield, and Beverly Whelton for their very helpful suggestions. Parts of the text also appear in ch. 2 of my book Descartes’ Metaphysical Physics.

Descartes’s Physics and Descartes’s Mechanics: Chicken and Egg?

Alan Gabbey

One of the nomological bases of mechanics is what is known today as “the principle of virtual work,” or of “virtual speeds,” to use the term employed by Jean Bernoulli when he announced the first modern formulation in 1717. A version of the principle in terms appropriate to this paper would be that the heights to which heavy bodies can be lifted severally through the expenditure of the same effort are inversely proportional to their respective weights. The principle goes back in one form or another to antiquity, yet there is no version of it to be found in Descartes’ Principles of Philosophy (Latin edition 1644, French edition 1647), the treatise in which Descartes published the foundations of his mechanical philosophy, of which notably the laws of nature in Part II are generally recognized as pioneering contributions to the establishment of modern “mechanics.” Furthermore, nowhere does Descartes tell his readers if or how the principle relates to his laws of nature. Its anomalous absence from the Principles seems therefore to have been a curious oversight.

The omission cannot be explained by assuming on Descartes’ part an ignorance of or lack of interest in a contemporary (or earlier) version of the principle, or by concluding that he must have thought it trivial or unimportant. Several times in his letters he stated his own version, which was among the clearest in the seventeenth century, and he used it twice in the composition of elaborate minitreasures on the theory of machines.

The first occasion was when he complied with Constantin Huygens’ request that he send him a few pages on mechanics, that is, on the five simple machines: the pulley, the inclined plane and the wedge, the windlass, the screw, and the lever. Accompanying his letter to Huygens of 5 October 1637 was an “Explanatory of machines with whose aid heavy loads can be lifted with a small force,” the opening paragraphs of which present and demonstrate Descartes’s version of the principle of virtual work (if I may call it that for the time being):

The invention of all these machines is based on only one single principle, which is that the same force [force] which can raise a 100-pound weight to a