REVIEW ESSAY

Descartes—Philosopher of the Scientific Revolution, Or Natural Philosopher in the Scientific Revolution?

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DESMOND CLARKE'S EXTENSIVELY RESEARCHED and factually rich biography of René Descartes is on balance a useful addition to the expanding empire of Anglophonic studies of the life of Descartes, a genre that barely existed a generation ago.[1] The book was well prepared by Clarke's significant previous contributions to Cartesian scholarship. Although it covers all of Descartes' life, the book concentrates on certain themes in the second half of his career, from the publication of the *Discours de la méthode* in 1637 down to his death in 1650 at the court of his last and most demanding patron, Queen Christina of Sweden. This is both the strength and the weakness of the book, as we shall see. The volume can be of considerable use to a

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wide, educated lay audience of advanced students or readers in any area of history or philosophy, including experts on cognate areas of early modern history or western intellectual history. However, there are also pitfalls for such readers, requiring some strong caveats. For the same reasons, expert readers, historians of the Scientific Revolution, and Cartesian scholars familiar with Descartes' natural philosophical and technical scientific interests, will also have some serious reservations. But before we investigate these shortcomings, we should explore the very real achievements of the book, which fall under four categories.

Clarke is at his best when exploring Descartes' theory of mind and issues concerning the nature of the human soul and its relation, indeed its "substantial union," as Descartes was wont to insist, with the body, including resulting problems about the passions of the soul, or emotions, as well as ethics, medicine, and a kind of psychosomatic therapy—all concerns of the last decade and a half of his life. Clarke's earlier book on Descartes' theory of mind is deservedly reputed amongst quite a few Descartes scholars as the best yet on the subject.[2] The present volume benefits from that work, glossing the results and setting them in a rich biographical context, informed by both the latest findings about Descartes' correspondence and the recent detailed bibliography of his published works.[3] Clarke's explanations in this, his favoured domain, are both clear and adjusted to the intelligent beginner, without denaturing or distorting this material. He places Descartes' texts and arguments inside quite dense narratives of the struggles, stratagems, victories and disappointments Descartes experienced in producing, "selling" and defending them. A clear picture comes through of Descartes' intellectual persona, psychological quirks, and typical strategies of intellectual combat. These parts of the book are compelling and hard to put down (an unusual compliment, I think, in the world of Descartes studies).

The second admirable strength in Clarke's account is the one that perhaps speaks most clearly to the intelligent lay reader—his clear exposition of the science/religion tensions and debates that ran

right through Descartes' later life. In 1633, Descartes recoiled from the condemnation of Galileo, withdrawing from publication his first draft system of corpuscular-mechanical natural philosophy, *Le Monde*. Later, he battled with Calvinist theological worthies (and civic authorities) at the University of Utrecht, and then at the University of Leiden. He also conducted a tortuous love/hate relationship with his former mentors, the Jesuits, alternately trying to seduce them into accepting his natural philosophy into their schools, or worrying endlessly—indeed almost in a paranoid manner—about their supposed opposition and perfidious machinations against him and his work. (303, 199, 287-8, 296-7) Clarke is very clear that we are not witnessing that "conflict" of science and religion trumped up in the nineteenth century and still, in simplistic form, haunting our understandings of modern science and its history.[4] Rather, Clarke establishes that in the age of Descartes we are dealing with contentions both between Catholics and Calvinists, and—what was sometimes more important—within each community, a situation further complicated by the fact that versions of neo-Scholastic Aristotelianism formed the higher educational glue for all denominations right across Europe. Moreover, despite sensationalist reinterpretations over the past century and a half, Clarke correctly holds that Descartes was a devout Catholic, but one whose interests, opinions and life style invited criticism, and suspicion, from both fellow Catholics and some of the Dutch Calvinists amongst whom he lived most of life after 1628. Each side, of course, included tolerant and worldly sophisticates, most often diplomats and men of affairs, it seems, rather than, for example, professors of theology. Of necessity Descartes often relied on such men, both French and Dutch, in search of cover, protection and patronage.

Amid the detail and blow-by-blow accounts of the religiously implicated controversies and debates, and the probable states of Descartes' mind and intention, Clarke also manages to put on view the underlying structural tensions. These had to do with a triangular set of relations among theological positions, views on biblical exegesis,

and agenda in natural philosophy. Rather than a conflict between science and religion, there was a kaleidoscope of varying and contested views on the proper relations among these three domains, each needing to be "properly" articulated to the others. The problem, of course, was that given the Reformation, and then the advent of that process we call the Scientific Revolution, no consensus solution was possible in European culture, indeed even within particular religious groupings. For example, pausing from his description of the Utrecht crisis involving Descartes' erstwhile avid academic supporter turned natural philosophical and theological loose cannon, Regius, Clarke lucidly sets out the grammar underlying much of the particular contestation, and detestation, on all sides, "Thus this Aristotelian distinction of form/matter was mapped onto the corresponding Christian belief in an immortal soul/mortal body. This solution implied that, if there was any tampering with the borrowed philosophical language, it would raise serious theological objections."(222) Clarke later offers an excellent summary of Descartes' entire mature position on the triangular relations among natural philosophy, theology and scripture, again showing the intellectual cul-de-sac created by the fact that, since the Reformation, all sides had continued to explicate the latter two with forms of Scholastic Aristotelian philosophy.(370, see also 342-3)

A third outstanding feature of Clarke's treatment draws upon another important area of his earlier work. This is his acute analysis of Descartes' actual notions about scientific explanation, as opposed to the oversimplified versions that are often purveyed in classrooms and even in serious scholarship. (161-68) Clarke was one of the first to show the actual ideas of the mature Descartes concerning the status of the corpuscular-mechanical explanatory models he advanced and about the requirements for adequate empirical and experimental support for them.[5] Clarke established that it is a mistake to take seriously Descartes' occasional claims to have been able to deduce—as if according to a mathematical ideal of "demonstration"—his entire system of natural philosophy from absolutely certain metaphysical prin-

ciples. This folklore arose from the strictly deductivist tone of Descartes' method in both his formal and more offhand statements about it. It is clear that, in his mature work, Descartes increasingly came to see that neither the details of particular explanatory models, nor the facts to be explained, could be deduced from metaphysics. Rather, he held that we may know with certainty from metaphysical deduction that the essence of matter is extension, but we cannot deduce from this truth more detailed explanatory models (concerning corpuscular sizes, shapes, arrangements and motions) that can explain various phenomena. The best one can say is that such models *should not contradict metaphysically derived certainties* (they must be "mechanical" in some sense). Hence corpuscular-mechanical explanatory models have a necessarily hypothetical character. Available evidence, and in particular the facts to be explained, also have an important bearing on the formulation of such detailed explanatory models and in the assessment of their "goodness" in view of explanatory power and scope of application.(154) In short, the mathematical ideal of demonstration does not extend to "scientific explanation," a Cartesian insight raising methodological and epistemological issues with which we have been dealing ever since.[6]

The biographical genre gives Clarke scope to flesh out these philosophical findings, by documenting Descartes' overwhelming interest in experiments and gathering of hands-on experience in all fields, from lens grinding to animal anatomy; from medicinal botany to aerostatics; from medical diagnostics to pendulum motion.(322-23) The mature Descartes read little, and often ignored books sent to him or dismissed them on cursory examination. But, as Clarke shows, this was not so that he could spend his late mornings in bed habitually meditating on first philosophy—something he told followers they should indulge in only once in a lifetime—rather it was so that, in his various Dutch hideaways, whose addresses were disclosed only to a tiny and select group at any time, he could experiment, peruse reports from others by voluminous correspondence, or, until he got into his fifties, work late into the night on his books and correspon-

dence.(234, 304,305) Indeed, in his compulsive concern for evidence and experience, Descartes himself was not so much different from those supposedly much more experimentally oriented corpuscular-mechanical savants one finds half a generation later at the Royal Society of London, or in and around the salons and lecture rooms of late-seventeenth-century Paris, where a veritable school or sect of Cartesian experimentalists thrived, as documented several years ago in yet another important book by Clarke.[7] What Descartes lacked, compared to the later so-called "experimental philosophers," was a genuine commitment to collaborative research among recognized peers, and an imperative toward new organizational modes to facilitate the same. That was not Descartes' style or personality, but then again, he lived in an age of clashing systems of natural philosophy, and just missed out on the emerging more normalized, sedate and clubby world of later seventeenth-century natural philosophizing, where theoretical contestation certainly continued to exist but was endemically somewhat muted, and ritually hidden from the public, at least by the great new "scientific" institutions.[8] Yet, Descartes was almost there, for as Clarke also shows, he was a canny tactician and negotiator of experimental work and its results, as for example in his dealings in person and by direct and indirect correspondence with the young Blaise Pascal over barometric experiments and the supervening theoretical question of the existence and nature of vacuums in nature. Nevertheless, Descartes' pragmatic, and sometimes even diplomatic, proceedings over experiments and experience were always overlaid with his prickly, devious and even paranoiac dealings and responses. Indeed it is this rich, relatively non-judgmental picture of Descartes' behaviour and personality that marks the fourth and most generically "biographical" key achievement of Clarke's book.

Clarke captures innumerable instances of Descartes' habitually secretive, reclusive, publicly masked and overtly tricky persona. This was a man who lived by the mottos "he lives well who is well hidden" and "masked I go forth."[9] Part of this, no doubt, was cultural, conditioned in Descartes and others by the superheated political and

religious tensions of the Baroque age, which also elicited intense and elaborate courtesy as a defence against incipient social breakdown and chaos. As Clarke well shows, Descartes, too, could turn on the elaborate Baroque etiquette and diplomacy, but usually only up to a point, quickly reached, when his resentment at personal or intellectual slights boiled over, or his creeping paranoia (sometimes well justified!) at intellectual or institutional cabals against him overtook his well-educated, rather neo-Stoical, attempts to control his passions rationally. But, aligned with these traits were also skills, eventually well honed, of intellectual combat and strategy. His habitual praising of critics in public whilst rejecting and reviling them behind their backs was not only "duplicitous," as Clarke maintains, (223) but also part of an elaborate array of tactics and ploys which Clarke uncovers—and shows most often, in the event, to have been ineffective or counterproductive. Descartes always persevered, however, and, as Clarke shows, his mature personality remained remarkably stable in these respects, even during the phase of malaise and relative loss of energy that overtook him as he entered his fifties. Two fine examples well dissected by Clarke will suffice. In one episode (231-2) Descartes went to great lengths to manipulate supportive friends like Marin Mersenne and Constantijn Huygens in his long battle with the leading Calvinist theologian and one-time Rector of the new University of Utrecht, Voetius. Descartes did this while walking a tightrope between wanting desperately to continue to embarrass Voetius in public as much as possible, and trying to avoid triggering his nemesis into a renewed and likely more dangerous campaign against him. In another tight situation a few years later, Descartes was hounded again by academic Calvinist theologians with excellent civic connections, this time in Leiden, with the extra danger that he might be summoned down to Leiden from his obscure, semi-rustic north Holland hideout for actual legal proceedings and possible punishment. Huygens, his partial political protector, secretary to the Prince of Orange (and father of Christiaan, the great late-seventeenth-century mathematician and natural philosopher), was brought into play, with Descartes him-

self, a lawyer by training, setting out in a carefully crafted letter an intricate array of possible lines of legal defence. (348) [10]

Clarke clearly sees, and communicates, that Descartes was "not simply a misanthrope."(248-9) He had important natural philosophical discoveries and systematics to promote and defend, and these, for better or worse, were the tactics he evolved, as we all do, in some kind of attunement with his underlying personality. Descartes was not without friends and allies, although some of these were rejected, alienated or otherwise abandoned for not toeing the Descartes line sufficiently well or loyally. He also had a wide, but shifting, circle of correspondents "who were instrumental in various ways in making his life's work successful."(249) Descartes was indeed a man on a mission, or perhaps on several missions that evolved over time, and the real issue that arises in this connection revolves around the nature of those missions. On this key point, Clarke's enterprise begins to totter, because, as we are about to see, he is not sufficiently precise or frank with the reader from the beginning about what kinds of disciplines, and hence what kinds of stakes, Descartes was playing for. Much of Descartes' behaviour as an intellectual combatant was grounded in or framed by the state of intellectual turbulence of his age. The questions arise: in which fields, domains and disciplines *exactly* was Descartes involved, and how did his strivings and struggles fit into the dynamics of those activities? It may sound odd to insist upon this point, but Clarke seriously mistakes these conditions, perhaps in the hope of not making things too complicated for lay readers; but, whatever the motive, he accordingly risks seriously misleading such readers. The point is that proper categorical understandings for early modern "science" are not arcane or beyond the reach of readers who are not expert in the history of science. If we refuse to engage this point, and Clarke so refuses, there is no way to generate anything like coherent, yet alone historically defensible, stories about Descartes' career. Clarke's problems begin therefore with his basic framework, and especially infect his treatment of Descartes' early career, which we have not yet addressed for this very reason.

Consider the following terms of analysis which appear early in the book and recur especially during the discussion, in the first three or four chapters, of Descartes' early education and years of supposed intellectual indecision and searching—say 1616 to 1628, when he was aged twenty to thirty-two. Clarke starts by claiming that Descartes is "best characterized as a philosopher of the Scientific Revolution."(1) His account is endemically woven around the categories of scholastic Aristotelianism and its contemporary challengers in the age of Descartes, "science" and "pseudo-science." By "science" Clarke means what Copernicus, Galileo, Kepler and Descartes all supposedly practiced and advocated, while "pseudo-science" is depicted as the domain of the rich melange of mystics, magicians, wild alchemists and neo-Platonists who proliferated in the late sixteenth and early seventeenth century.(52) As for the neo-Scholastic Aristotelianism taught in both the Catholic and Protestant universities of the period, it is "desiccated and obsolete" (5) and a complete obstacle to any advance in explaining or understanding natural phenomena. Descartes is presented as tempted by pseudo-science in his (extended) "youth," but after many years, by 1628, Descartes sorts himself out as an advocate of "science." All the while, of course, he harboured doubts about that vacuous, desiccated Scholastic Aristotelianism, and after 1628 set out to defeat it, emerging as one of the greatest, if not *the* greatest, you guessed it, "philosopher of the Scientific Revolution." Clarke thus signals to the lay reader that actors in the period saw "the Scientific Revolution" in terms of the rise of "science" to defeat pointless Scholasticism and the false promises of the trendy "pseudo-science," with its real time narrative or voice-over being supplied by "philosophers" of this event, pre-eminently Descartes.[11]

Now, the problem here is that while such an interpretive framework may appeal to those who have never dipped into the last two generations of professional literature on the history of science and the Scientific Revolution—and such lay readers may be very sophisticated in other historical or philosophical terms—this framework is quite simply inadequate—dare I say desiccated and obsolete? This is

not the place for a lecture, or a book, on the historiography of the Scientific Revolution, but they are not hard to find.[12] Clarke's approach, redolent of views of the Scientific Revolution popular in expert domains before the middle of the last century, leads to a misrepresentation of a number of issues. These include Descartes' vocation as a philosopher of nature, in which he contended with other philosophers of nature; his commitment to corpuscular-mechanical natural philosophy, imbibed from his absolutely crucial mentor, Isaac Beeckman, along with an interest in something called "physico-mathematics"; his crucial work in optics along the lines of a corpuscular-mechanical physico-mathematics; the actual terms and goals of his work on method, and the reasons for his likely abandonment of that dream, after 1632; and, finally, the nature of his work on vortices and why this work was not "astronomy" as Clarke repeatedly labels it.(234, 294) We need to address some of these issues, and, in order to do that, we must first see if we can, in short compass, rectify some of the damage that Clarke's historiographical framework can create for the lay reader.

The best recent early modern historiography has largely discarded the word "Science" as some emerging modern essence, and focused instead on the actual constellation of traditions and disciplines devoted to seeking knowledge of nature in early modern Europe. Chief among those fields was natural philosophy.[13] Early modern natural philosophy was not just the Scholastic Aristotelianism of the universities. It was an entire elite sub-culture and field of contestation. When one "natural philosophized" one tried systematically to explain the nature of matter, the cosmological structuring of that matter, the principles of causation, and the methodology supposedly used for acquiring or justifying such natural knowledge. Of course, the dominant genus of natural philosophy was Aristotelianism in various neo-Scholastic species, but the term applied to alternatives of similar scope and aim; that is, to any particular species of the various competing genera: neo-Platonic, mechanistic or, later, Newtonian. Natural philosophers learned what I call the "grammar of natu-

ral philosophizing" at university while studying the hegemonic school of thought, Scholastic Aristotelianism. Even alternative systems followed the rules of this game: everyone, Aristotelian or non-Aristotelian natural philosophers alike, learned what Ian Maclean felicitously terms "the instruments of thought" through this process.[14] All natural philosophers and natural philosophies constituted one sub-culture in dynamic process over time.[15] At its climax in the early and mid-seventeenth century—the age of Descartes—the "Scientific Revolution" was a set of transformations, a virtual civil war, inside the seething, contested culture of natural philosophizing, as the hegemonic and deeply institutionalized neo-Scholasticism of the Reformation and Counter Reformation was challenged intellectually and organizationally.

Along with the study of the continuities and changes in early modern natural philosophy has come attention to those disciplines then thought to be superior to it, such as theology, cognate with it, such as mathematics, or subordinate to it, as in the traditional "mixed mathematical sciences" of hydrostatics, statics, geometrical optics, geometrical astronomy and harmonics. These are particularly important to understand if the agenda of Descartes and other mathematically literate natural philosophical radicals are to be comprehended. The term "mixed mathematics" belonged to Aristotelianism, referring to this group of disciplines intermediate between natural philosophy and mathematics and subordinate to them both. A natural philosophical account of something was an explanation in terms of matter and cause, and, for Aristotelians, mathematics could not do that. The mixed mathematical sciences used mathematics not in an explanatory way, but instrumentally to represent physical things and processes mathematically. So in geometrical optics, one used geometry, representing light as light rays. As useful as this may have been, it did not get at the underlying natural philosophical questions: "the physical nature of light" and "the causes of optical phenomena." Similarly, geometrical astronomy was an instrumental discipline where non-realistic geometrical models were used to predict planetary positions;

cosmology, in contrast, labels a dimension of natural philosophy, explaining the nature of stars, planets, sun and earth in terms of matter and cause.

So Descartes was not involved in inventing "science" to defeat "pseudo-science" and a "useless" Scholastic Aristotelianism. Descartes lived during a period of intense competition amongst natural philosophers, as the still-dominant Scholastic Aristotelianism was challenged by varieties of neo-Platonism, some imbued with magical aims or tied to programs of religious and political reform. The mechanical philosophy of nature was constructed by Descartes and a handful of others, who hoped to resolve the conflict of natural philosophies in a way which promised progress in knowledge of, and command over, nature, without the need for social reform or political or religious upheaval. This is not the *de novo* invention of "science" by peculiar geniuses, but a turbulent process within an already existing cultural form and social institution—natural philosophizing.

Additionally, much of this process was played out in a small region of the total field of natural philosophizing, where, according to Scholastics, natural philosophy met up with the merely instrumental and non-explanatory mixed mathematical sciences. This is where certain kinds of natural philosophical radicals, those with very good mathematics credentials, made their moves, under a banner that some of them enunciated, and which we can adopt as an historiographical category as well, to wit, "physico-mathematics."[16] This is very important because both Descartes and his mentor Beeckman specifically congratulated themselves as being among the relatively few physico-mathematicians in Europe.[17] The term physico-mathematics denoted a commitment to radically revising the conventional Scholastic Aristotelian view of the mixed mathematical sciences as subordinate to natural philosophy, non-explanatory and merely descriptive. The mixed mathematical disciplines were somehow to become more intimately related to natural philosophical issues of matter and cause. Paradoxically, and this is very important, physico-mathematics was not about the mathematization of natural philosophy. Rather the

mixed mathematical sciences (which were already "mathematical") were to become, as I have recently taken to saying, more "physicalized," more closely intertwined with or integrated into natural philosophizing, regardless of which specific genre of natural philosophy the budding physico-mathematician endorsed.[18] "Physico-mathematical" initiatives began to appear in the later sixteenth century. There were abortive attempts, for example by the young Galileo and several older contemporaries, to bring traditional mechanics—statics, hydrostatics and the study of the simple machines—into natural philosophy, thus both moving natural philosophy in an anti-Aristotelian direction and promoting mechanics to the core of natural philosophical systematics.[19] The heightened natural philosophical contestation of the early seventeenth century intensified the proliferation and competition of physico-mathematical gambits, and many variants can be identified, including those of Beeckman and Descartes in their joint work in 1618-19.

Neither these ideas about natural philosophy and its dynamics, the mixed mathematical sciences nor the radical agenda of physico-mathematics are beyond the ken of relative beginners in the history of science. We routinely teach them to advanced undergraduates. No matter what form one's ultimate narrative and explanations take using these categories, they arguably supplant the idea of a ballet performed by three blocks of Whiggish conceptual concrete—an emergent "science," a dangerous and ill-fated "pseudo-science," and a lumbering, vacuous, dead weight of (oddly ubiquitous) Aristotelianism. Accordingly, let us now put these categories to work to rectify some of Clarke's perspectives, especially on the early career of Descartes.

Clarke believes that Descartes' commitment to corpuscular-mechanical natural philosophy, including a mechanistic physiology, resulted from his exposure to the writing of Simon de Caus, engineer and automaton maker extraordinaire, as well as from first-hand experience of these Baroque wonders.(92-3) Clarke depicts this as one shaft of clear intellectual inspiration amid Descartes' own youthful

confusions and the array of (apparently self-evidently) "scientific" and "pseudo-scientific" positions proliferating at the time. This is misleading. Descartes first learned about corpuscular-mechanism as a viable alternative within the field of natural philosophizing from his friend and mentor Beeckman, one of only two people from whom anyone could have imbibed this perspective at the time (the other being the brilliant but unpublished Englishman, Thomas Harriot).[20] Despite having much interesting material on Descartes' long and often strained relations with Beeckman, Clarke makes no mention in the book of this absolutely crucial and seminal part of their relation.[21]

Corpuscular-mechanism, as Beeckman and later Descartes and others practiced it, was not simply the adoption of some sort of ancient atomist matter theory. There were plenty of advocates of such styles of what historians now call "qualitative atomism." What sets off corpuscular-mechanism as a unique genus of natural philosophy was the addition to atomism of a commitment to devise a "mechanics" or "science of motion" embodying laws governing the motion and exchanges of motion in the world of micro corpuscles. This would be the causal dimension of such natural philosophies. Qualitative atomists had no such imperative, the causal registers of these natural philosophies being filled out from traditional notions of spiritual or immaterial forces, attractions, repulsions, antipathies and sympathies. The search for a "mechanics" to "run" the world of micro particles was one sense in which the traditional mixed mathematical science of mechanics was being articulated and renegotiated in a physico-mathematical direction. To revel in automata, or read engineers and students of more traditional mechanics, like de Caus, would not make you a corpuscular-mechanist: there were many devotees of mechanics and mechanical contrivances who were not corpuscular-mechanical natural philosophers.

Beeckman is of supreme importance for Descartes, de Caus of very marginal import. Descartes' corpuscular-mechanism is central to his entire career. The manner in which he held and developed it at various stages of that career, including how he practiced subordinate

sciences in relation to it, are the guide thread and theme of his life as, yes, a philosopher of nature, contending with other philosophers of nature. Needless to say—but it still needs saying—all this should imply to the careful reader why Descartes is not the "philosopher of the scientific revolution," except in modern courses in philosophy of science and history of philosophy. He was a player (as the bulk of Clarke's prodigious research actually shows), not a meta-commentator, an immensely creative, combative and influential natural philosopher in a process that we call the Scientific Revolution. During his generation, this process was in large measure a conflict of such natural philosophies, and included battles about the development, and natural philosophical import, of the traditional subordinate sciences.

Clarke also pays no attention to the physico-mathematics of Beeckman and Descartes. Of the activities Descartes and Beeckman pursued in 1618-19 in their earliest interactions, Clarke speaks at length only of Descartes' *Compendium of Music*. In this work Descartes treated the mixed mathematical science of music theory almost entirely in a traditional way. Descartes gave very few hints of the radical physico-mathematics he was simultaneously pursuing with Beeckman in the areas of hydrostatics, optics, and even in their study of falling bodies (where they concluded that no physico-mathematical progress was likely).[22] In hydrostatics, for example, Descartes took the solid, rigorous results of the great Dutch engineer and mathematician Simon Stevin, and tried to show Beeckman that the rigorous geometrical results actually follow from the behaviour of underlying particles.[23] In the process he began to work out his ideas about the "dynamics" guiding the behaviour of such particles, the distant forerunner of his later "rules (or laws) of nature" in *Le Monde* and the *Principia*. The work was not entirely successful, but set a very deep agenda and level of aspiration in the young Descartes—he was not simply physically travelling around and intellectually flailing around over the next ten years. Indeed by around 1626 he followed up some early physico-mathematical work on optics from 1620 with

a brilliant and stunning result, one that Clarke declines to discuss at all—the discovery of the law of refraction of light and the attempt to explain the new law in terms of the dynamics of light.[24] Clarke continually talks about Descartes' optics work in terms of his very real attempts to get lenses ground to instantiate the law (81, 99, cf. 108, 136)—but this is the tail on a very profound natural philosophical and physico-mathematical dog. After all, the law of refraction was, leaving aside Kepler's laws of planetary motion, only the second physical law ever discovered (after Archimedes' law of the lever, circa 200 BCE). What Descartes did in optics was absolutely central to his standing and agenda as a natural philosopher and physico-mathematician. The short story would run as follows:

In Paris in 1626/27 Descartes, collaborating with the mathematician Claude Mydorge, discovered the long sought law of refraction. In my reconstruction, this was accomplished using only traditional mixed mathematical optics and yielded, for technical geometrical reasons, a law of cosecants, not (the mathematically equivalent) law of sines. Then, upon that particular geometrical representation of the law, Descartes performed some physico-mathematical magic: he transcribed into "dynamical" terms the geometrical parameters embodied in his diagrammatic representation. It was as though Descartes, wearing his "physico-mathematician" spectacles, believed he could literally "see the real, natural philosophical, causes" at work by peering into his geometrical representation of the long sought-for law.[25] He was articulating and extending the kind of ideas about the dynamics of corpuscles he had begun to introduce into his physico-mathematicial version of hydrostatics back in 1619. So, by 1627 the young Descartes, *physico-mathematicus*, had a great result, a solution to a classical mixed mathematical problem and a radical physico-mathematical move to adduce the putative mechanical causes of the new law.

When, a few years later, Descartes came to compose a system of natural philosophy, these ideas about the dynamics of corpuscles were embedded in a metaphysical and theological legitimation and

placed at the centre of the new corpuscular-mechanical natural philosophy. This in turn helps to explain things about Descartes' laws of nature that Clarke misses. Descartes' laws apply not to actual bodies in translation in space and time, but to instants of time, detailing the behaviour of instantaneously exerted absolute quantities of force of motion and their instantaneously exerted directional tendencies, which Descartes called "determination." When Clarke talks about Descartes' development of the laws in his correspondence during composition of *Le Monde*, he calls Descartes' first law a law of inertia (102), implying a much more direct relation to Newton's later law than actually exists. Additionally, what Descartes is doing in the passages Clarke cites is recalling Beeckman's original (1613) version of, yes, something like the classical law of inertia, a form Descartes, with his interest in instantaneous states of the forces of motion and directional tendencies to motion of corpuscles, was in the process of modifying and adapting.[26] Clarke's story is garbled and misleading, and for this there is no excuse: though the correct accounts of the optics and nature of the mechanics and dynamics are available in the literature, nothing relevant is cited.[27] The picture that begins to emerge is that Clarke perhaps should have limited his book to those themes in the later career of Descartes that, we have agreed, he treats so well, including a detailed study of Descartes' personality and tactics. But an intellectual biography needs to deal seriously with all the fields, traditions and disciplines in which the subject played.[28] Compared, say, to Gaukroger's intellectual biography of Descartes, Clarke's falls far short.

This leads us to the issue of Descartes' systematic natural philosophizing in *Le Monde* and the *Principles of Philosophy*, and in particular to his often berated and underrated theory of vortices as the explanation for planetary motions in the Copernican system. Here again, we are rather let down. Clarke repeatedly alludes to Descartes' work in "astronomy."(4, 110) Well, astronomy was of course a mixed mathematical science in which merely instrumental (not realistic) geometrical models were constructed to enable the prediction of

planetary positions. To speak in matter and cause terms about the real structure, makeup, and movements of the heavenly bodies was to engage in that part of natural philosophy called above cosmology. Taken as a mere predictive system, Copernicus' astronomy was inoffensive and remained allowable even under Catholic regulations after the 1616 condemnation of realist Copernicanism—the claim that the Copernican system was (natural philosophically) true to reality. Descartes had no interest in astronomy in the traditional sense of hypothetical model building; neither did Galileo—he specialized in observational astronomy of course. Rather, Descartes wanted to emulate Johannes Kepler, the radical realist Copernican *par excellence*, and attempt to give matter theoretical and causal explanations of the nature of the sun, planets, earth and the movements of the planets, including planet earth. This aspiration amounted to a desire to physicalize astronomy, to render Copernican astronomy in physico-mathematical terms as an organic part of natural philosophy. The problem, or the opportunity, depending upon where you stood, was that realist Copernicanism could in no way comport with Aristotelian natural philosophy; it demanded one or another systematic anti-Aristotelian approach. [29]

In this connection, Beeckman and Descartes agreed that Kepler had been on target in seeking a physicalization of Copernican astronomy; the problem was that Kepler's preferred natural philosophical alternative to Aristotle, of an elaborated neo-Platonic type, was completely unacceptable to them. Hence Descartes' agenda when he came to write a system of natural philosophy. His answer was tied up in his theory of vortices, a serious conceptual construction, which made use of his ideas about corpuscular dynamics and arguably had a veneer of physico-mathematics about it. It was not an added extra to his natural philosophy, nor something separate from his thinking about corpuscular dynamics: it was the engine room of his cosmology in his natural philosophy, and it articulated and exemplified his dynamics. None of this is on view in Clarke's account of Descartes' "astronomy," including his brief discussion of the vortices, and his

odd account of the dynamics (the laws of nature, wrongly described as laws about translation in space and time) as happily added onto the system on the occasion of Descartes' writing it all up. (293, cf. the similar remark about the laws of nature in *Le Monde* 119)

Finally, in this short tour of rectification of the terms and trajectories of Descartes' earlier work, we need to examine the issue of Descartes' method, and his main methodological tract, the *Rules for the direction of the mind*. Clarke is aware that the *Regulae* was composed and revised in several strata over the years 1619-28. He cites Jean-Paul Weber who, as it happened, first established this incredibly significant point, but Clarke's note does not credit Weber with this finding. It is about a tangential matter and in fact makes an incorrect assertion about Weber.[30] Moreover, Clarke consistently refuses to make any definitive statement about when he thinks Descartes formulated his method, how far the formulations went, and ultimately why the text containing the fullest statement of the method, the *Regulae*, was abandoned in mid sentence. (61-63, 65-66, 85, 91) He is also in the end ambiguous about what he thinks Descartes' strange dreams, or reports of dreams, on the night of 10-11 November 1619 may have had to do with his overheated post-adolescent fantasy of method, which also first hit him at around this very time. Clarke may have a settled view on these issues, but the reader, especially the lay reader, will not easily tease out a position from Clarke's extensive and somewhat scattered remarks on these questions.

A clear and convincing story, however, can be presented, and one moreover that builds precisely on the findings of Weber, of whom Clarke apparently approves. This is because Weber's work has been extended and modulated on the precise issue of what Descartes believed about method, and when he believed it, although none of this is cited or discussed by Clarke. Here is one variant.

Again, as opposed to Clarke's view of a searching and wandering (physically and intellectually) Descartes in the years 1618-28 (93), he not only had physico-mathematical hydrostatics, optics and piecemeal corpuscular mechanism on his mind, but he also in 1618-9

had hit on a series of grand intellectual projects related to method. In 1618-19 Descartes envisioned in quick succession two breathtaking projects reaching beyond the physico-mathematics idea he had picked up from Beeckman: universal mathematics and universal method. First, he imagined his universal mathematics as meant to encapsulate and transcend "mere" physico-mathematics. Then, in a peak of excitement later in 1619, around the time of the dreams, he envisioned his universal method, which meant to absorb universal mathematics and move on much further. Eventually, by the late 1620's, the failure of these visions drove Descartes toward his explicit vocation in *systematic* corpuscular–mechanical natural philosophy, a program he had never before embraced.

Since the early Beeckman days in 1618-19, Descartes had pursued an analytical, problem-solving agenda in mathematics (mentioned by Clarke), which in these respects seemed to him to resemble his physico-mathematics (not mentioned by Clarke). Descartes worked again in a piecemeal way, but always seemed to be trying to convince himself that general protocols could be found for solving problems in both algebra and geometry.[31] Descartes thought that physico-mathematics, too, could be brought into this unified orbit. This hope triggered in 1619-20 his dream of a unified analytical approach to all mathematically based disciplines—practical, pure and physico-mathematical—to which he appropriated the already circulating name "universal mathematics."

According to Weber and his supporters, all this is recorded in an early fragment, which later was embedded in the text of the *Rules for the direction of the mind*, the so-called rule 4B.[32] Universal mathematics was quite a program, or delusion, and one could be forgiven for thinking that in 1619 this would have been enough for the swaggering young Descartes. But within a matter of months in 1619, the overheated conception of universal mathematics gave way to the even more encompassing mirage of a universal method. According to the method, all rationally obtainable truths subsist in a unitary network of deductive linkages, which humans may explore by intuiting

individual truths and deducing valid links between them. Method essentially consists of a set of practical hints or heuristic rules to aid the intuiting and deducing mind in traversing this network. This much of the method—that is, most of it—was also inscribed in a text Weber termed rule 4A, which Descartes inserted into the *Rules for the Direction of the Mind*, along with most of the texts of rules 1-3 and 5-11, with some small exceptions.[33]

Now, a key point here is that many modern scholars now hold that grand, set-piece doctrines of scientific method, such as Descartes', cannot and do not control and guide living practice in any given field of research, let alone across the entire gamut of disciplines. In my view, following on from the method scepticism of the likes of Kuhn and Feyerabend, all grand method doctrines—Descartes', Newton's, Mill's, Popper's, Lakatos'—share a specific discursive structure which simultaneously cripples their abilities to deliver the cognitive goods they promise, yet create for audiences illusions that they can so deliver. Hence *we* know that Descartes cannot have succeeded, and that he very likely succumbed to the textual persuasion of his own method discourse, and genuinely believed in it, at least until a crucial moment I will discuss shortly.[34] All this entails Descartes' technical achievements in mathematics, the mixed sciences, and natural philosophy cannot and should not therefore be explained as applications of his method. Modern scholars are finding more plausible reconstructions of how Descartes accomplished his key discoveries.[35] A good example is the contrast between how he actually discovered the law of refraction of light, and its mechanical rationale, mentioned earlier, and the fairy tale he tells about this in rule 8 of *Rules for the direction of the Mind*.[36]

To return to Descartes' early adventures, thus critically armed: In 1627-28, after his optical breakthrough, and working partly in the shadow of Marin Mersenne's cultural battle against both radical scepticism and religiously heterodox natural philosophies, he picked up universal mathematics and method again in detail, and tried to write a unified treatise about his earlier dream of a methodologically sound

universal mathematics, the unfinished *Rules for the direction of the mind*.[37] This final plan, in the view of Weber and others, would broadly involve rules 12 to 21 and a key part of 8.[38] I have argued elsewhere that this project did not blossom into the intended magisterial work of method and universal mathematics, but collapsed under its own weight of self-generating problems and contradictions. However, it was precisely these problems in particular that shaped Descartes' next, decisive career moves in 1629–30 when he began working on his dualist metaphysics and on his system of corpuscular-mechanical natural philosophy.[39] Clarke shadows some of these claims, clouds some of them, repeats some of them, and never properly cites the relevant background literature.[40]

Descartes' fantasy projects peaked at two moments: first in 1619-20 when he hit on universal mathematics, leading quickly to the first gleams of the method; and then late in the 1620s, after the optical breakthrough, with the composition of most of the *Rules*. But the projects of method and universal mathematics failed. The story of the young Descartes is not just travel and indecision. Rather, it revolves around the intended and unintended entanglements of two trajectories—in physico-mathematical natural philosophy, and in analytical mathematics, promoted to fantasy programs in universal mathematics and method. The key point for those wishing to study Descartes' later career in detail, as Clarke has done in his areas of strength as noted earlier, is this: Descartes' later agenda and identities grow out of the already rich and entangled enterprises of his early years. After the failure of the *Regulae*, and of universal mathematics and method with it, Descartes had to return to the two real but largely separate cultural games in town available to his talents—he retreated to a more isolated and independent high level analytical mathematics; and he (re)turned, separately, to the field of natural philosophizing. But there was a catch, a lingering hankering after a grander, more legitimated, more unified and hence more culturally triumphant vision. This of course was Descartes' remaining lifelong attempt to provide through his dualist metaphysics a grounding of certainty for both mathematics

and, in the limited way discussed above, in his natural philosophy. He still yearned to be the hegemon of both, not just through brilliant and novel work, but through immunizing both from scepticism, and the natural philosophy in particular from religious and politico-cultural radicalism.

As for the big picture on "Descartes and the Scientific Revolution," far from labelling him its "philosopher," we should rather say the following: Descartes' natural philosophy (and legitimatory metaphysics), along with his work in the subordinate (and rapidly changing) sciences, was in the weave of the process we label the Scientific Revolution; it was not in some trans-historical position "meta" to it. Nor was Descartes graced with superhuman insight into how science might be parsed from pseudo-science once and for all. These are the things about which the players played. Descartes was a brilliant participant, a canny but difficult player, not entirely successful in his immediate surroundings but of immense influence over the larger trajectories of natural philosophy and the subordinate sciences for the next few generations.[41]

In sum, it is surprising and disappointing that this book deals so poorly with Descartes' early career and his lifelong core concerns with natural philosophy and its subordinate mixed (and increasingly physicalized) sciences. A generation or two ago, historians of science did not appreciate as they do now the category of natural philosophy, nor did they attend to its dynamics as such. Nor, moreover, was there much understanding of what contemporaries understood by the mixed mathematical sciences, their declared status and the increasing challenges thereto. Clarke is no stranger to the history of science. One of his supreme strengths as an historian of philosophy has always been his literacy in, and assimilation of, state-of-the-art history of science research. His work on the school of late-seventeenth-century, more experimentally focused, Cartesian mechanists was ground breaking. There certainly is no lack of knowledge or skill behind this outcome; rather, I suspect an error of judgement in framing the book and its presumed audience.

It is clear Clarke has no problem expounding for our "intelligent lay audience" complex issues about mind-body relations, Cartesian physiology, the doctrine of the passions, and seventeenth-century Catholic and Calvinist theological and biblical exegetical tangles. However, it seems to have been decided that other issues are too hard to be thus expounded. These include the actual terms of the Copernican debate; the real nature of natural philosophical contestation and turbulence; the actual character of the mixed sciences, and the nature of the debates about their possible shift to physico-mathematics; and the post-Kuhnian problem of anybody, Descartes included, apparently believing in a unique, transferable and efficacious general "method." On the question of what can and cannot be presented to the intelligent lay reader, I must respectfully differ. Quite apart from the relevant scholarly research on these matters, we also have history of science textbooks, such as those by Peter Dear and John Henry, which have done exactly what was avoided here, to wit, refuse to dumb down for beginners the terms and categories of discourse about the Scientific Revolution.[42] I can also add on a personal note, from thirty years' experience, that second and third year undergraduates can be instructed in the required categories, and in the sorts of explanations and narratives that result from using them.

In its strong domains, this book is well written, and avoids the crankiness and idiosyncrasy that have infected a couple of other recent attempts at biography of Descartes. Still, it might have been a better idea to eschew a full biography and stick with the treatment of Descartes' intertwined trajectories in physiology, medicine, psychology and mind/body relations, ethics and metaphysics over the last decade and a half of his life. For this reason the preferred—and indeed essential—intellectual biography of Descartes must still remain the magnificent work of Gaukroger. Accordingly, although Clarke's book, for its virtues, should be on every shelf of early modern intellectual history, history of philosophy, or history of science, it cannot be recommended to the non-expert *tout court*. Large swathes of Clarke's strong material may be taken with confidence, but the book

in its entirety should be ingested only if accompanied by very specific caveats and a long specialist's prescription of corrective conceptions and literature.

Notes

[1] Stephen Gaukroger, *Descartes: An Intellectual Biography* (Oxford: Oxford University Press, 1995); Richard Watson, *Cogito Ergo Sum: the Life of René Descartes* (Boston: David R. Godine, 2002); A. C. Grayling, *Descartes: The Life of René Descartes and Its Place in His Times* (London: Free Press, 2005).

[2] Desmond Clarke, *Descartes' Theory of Mind* (Oxford: Clarendon Press, 2003).

[3] Matthijs van Otegem, *A Bibliography of the Works of Descartes* (1637-1704), 2 vols. (Utrecht: Leiden–Utrecht Research Institute of Philosophy, 2002); René Descartes, *The Correspondence of René Descartes 1643*, ed. Theo Verbeek, E.-J. Bops and J. van de Ven (Utrecht: Zeno Institute for Philosophy, 2003).

[4] For the Protestant context the best of the new historiography of early modern "science" and religion comes from the pen of Peter Harrison, *The Bible, Protestantism and the Rise of Natural Science* (Cambridge: Cambridge University Press, 1998). On the general revision of archaic views of this matter in the past generation, the starting point is the pedagogical classic, John H. Brooke, *Science and Religion: Some Historical Perspectives* (Cambridge: Cambridge University Press, 1991).

[5] Desmond Clarke, "Descartes' Use of 'Demonstration' and 'Deduction'," *The Modern Schoolman* 44 (1977), 333-44.

[6] The other great contributor to these insights about Descartes was the brilliant Cambridge historian and philosopher of science, Gerd Buchdahl, in his *Metaphysics and the Philosophy of Science from Descartes to Kant* (Cambridge, Mass.: MIT, 1970), especially the hundred-page chapter on Descartes, and within it, pp. 96-7 and 118-26. Clarke's work has always been much more accessible to both the lay and expert reader, although it must be said that Buchdahl more consistently and pertinently stressed the non-trivial and varied ways in which metaphysical presuppositions still condition explanation in the Cartesian dispensation. A cursory reader of the present book might still get the impression that metaphysics plays little role in Descartes' theory of explanation, the point being somewhat occluded in Clarke's scattered but otherwise very useful remarks on the subject. A. I. Sabra also flagged some of these issues quite early on in the course of his pioneering work on optics and theories of light in the Scientific Revolution. A. I. Sabra, *Theories of Light from Descartes to Newton* (London: Oldbourne, 1967), 21-45. For Clarke's and these others' views as now routinely consensual, see J.A. Schuster, "René Descartes" in *Encyclopedia of the Scientific Revolution*, ed. W. Applebaum (New York: Garland Publishing, 2000), 187-8.

[7] Desmond Clarke, *Occult Powers and Hypotheses: Cartesian Natural Philosophy under Louis XIV* (Oxford: Clarendon Press, 1989).

[8] Stephen Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: University of Chicago Press, 1994), famously announced the advent at the early Royal Society of London, from the early 1660s onward, of an atheoretical "experimental science" of "matters of fact" exchanged in a culture of gentlemanly trust. He ignored the continuation of heated natural philosophical contestation in muted circumstances and under a public rhetoric of "matters of fact only." Moreover, no fact in natural philosophy or any science is not "theory-loaded," as almost any first year student in History and Philosophy of Science or Science and Technology Studies anywhere in the world can tell you. On the myth of merely matter of fact science at the Royal Society, see J.A.Schuster and A.B.H. Taylor, "Blind Trust: The Gentlemanly Origins of Experimental Science," *Social Studies of Science* 27 (1996), 503-36. For a clear demonstration that the contemporary Florentine Accademia del Cimento was also rife with natural philosophical agenda and conflicts, hidden below a public façade, see the important work of Luciano Boschiero, *Experiment and Natural Philosophy in Seventeenth-Century Tuscany* (Dordrecht: Springer, 2007).

[9] Indeed Clarke provides the best accounting of Descartes' various travels and likely residences available anywhere between two covers. Descartes announced "Bene vixit, bene qui latuit" as his motto to Mersenne in April 1634 (in the standard Charles Adam and Paul Tannery edition of his works, Volume I, p. 286). Descartes proclaimed "larvatus prodeo" (masked I go forth) in the middle of some fragmentary youthful ruminations preserved in Adam and Tannery, Volume X, p.213.

[10] The matter petered out with some very modern-looking backtracking and self-serving befogging of the issues by the University of Leiden "executive management," as they would now term themselves, more concerned with internal decorum amongst professors, and public image amongst likely supporters and clients, than with engaging Descartes and his patrons in endless technical and high powered intellectual and legal wrangling. Clarke's account will have every veteran of modern university politics and public relations laughing out loud. (350)

[11] Clarke's problems here do less damage when he is deep in the toils of Descartes' mature metaphysical, theological, ethical and psycho-somatic concerns. However, the underlying historiographical categories and agenda are not without consequences for Clarke's treatment of the older Descartes, though it would take another review to tease them all out, a path of perhaps decreasing intellectual profits. Nevertheless, readers can (and should) do it for themselves, as they read the latter portions of the book, having considered some of the criticisms we are about to explore here.

[12] See, for example, H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago: University of Chicago, 1994). Relevant articles may be found in W. Applebaum, ed. *Encyclopedia of Scientific Revolution*, using the Editor's "Introduction and User's Guide" and the "Topical Outline," especially Section V, "Historiographical Issues and Interpretations," p. xviii, with its initial list of eleven entries. For an up-to-date, historiographically sophisticated textbook treatment, see Peter Dear, *Revolutionizing the Sciences: European Knowledge and its Ambitions, 1500-1700* (Princeton, Princeton University Press, 2001). See also on open web access, a distance learning beginner's textbook, J.A. Schuster, *The Scientific Revolution: An Introduction to the History and Philosophy of Science* (1995) at http://hist-phil.arts.unsw.edu.au/staff/staff.php?first=John&last=Schuster

[13] To place the evolution of natural philosophy, and in particular the shifting patterns of its relations to other enterprises and disciplines, at the centre of one's conception of the Scientific Revolution is not novel, and more scholars are realizing the value of such a perspective, but neither is it obvious or agreed upon in the scholarly community. Many older discussions, and some contemporary ones, are marred by a tendency to lump the culture of natural philosophizing under an anachronistic label of "science," thus obscuring the possibility of speaking convincingly about the internal texture and dynamics of the seething, contested culture of natural philosophy and its patterns of change over the period. H. Floris Cohen's massive survey of Scientific Revolution historiography (Cohen, *The Scientific Revolution: A Historiographical Inquiry*) illustrates that the term "natural philosophy" has been endemically present in the literature, but not systematically theorised, often serving as a synonym for "science" or (some of) the sciences. Recent attempts to delineate the category of natural philosophy and deploy it in Scientific Revolution historiography include John A. Schuster, "The Scientific Revolution," in *The Companion to the History of Modern Science*, ed. R. C. Olby, G. N. Cantor, J. R. R. Christie, and M. J. S. Hodge (London: Routledge, 1990), 217–42; John A. Schuster and Graeme Watchirs, "Natural Philosophy, Experiment and Discourse in the Eighteenth Century: Beyond the Kuhn/Bachelard Problematic," in *Experimental Inquiries: Historical, Philosophical and Social Studies of Experiment*, ed. H. E. LeGrand (Dordrecht: Reidel, 1990), 1–48; Andrew Cunningham, "Getting the Game Right: some Plain Words on the Identity and Invention of Science," *Studies in History and Philosophy of Science* 19 (1988), 365–89; Andrew Cunningham, "How the *Principia* Got its Name; or, Taking Natural Philosophy Seriously," *History of Science* 24 (1991), 377–392; Peter Dear, "Religion, Science and Natural Philosophy: Thoughts on Cunningham's Thesis," *Studies in History and Philosophy of Science* 32 (2001), 377–386; Peter Harri-

son, "The Influence of Cartesian Cosmology in England," in *Descartes' Natural Philosophy*, ed. Stephen Gaukroger, John Schuster and John Sutton (London: Routledge, 2000), 168–192; Peter Harrison, "Physico-Theology and the Mixed Sciences: The Role of Theology in Early Modern Natural Philosophy," in *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy,* ed. Peter Anstey and John A. Schuster (Dordrecht, Springer, 2005), 165-183. ('Science of nature' does not mean modern sciences, but denoted at the time precisely natural philosophy as a systematic enterprise.)

[14] Ian Mclean, *Logic, Signs and Nature in the Renaissance* (Cambridge: Cambridge University Press, 2007), chapters 4 and 5.

[15] John A. Schuster, "The Scientific Revolution"; Schuster and Watchirs, "Natural Philosophy, Experiment and Discourse"; John A. Schuster, "L'Aristotelismo e le sue Alternative", in *La Rivoluzione Scientifica,* ed. Daniel Garber (Rome: Instituto della Enciclopedia Italiana, 2002), 337-357

[16] Peter Dear, *Discipline and Experience: The Mathematical Way in the Scientific Revolution* (Chicago: University of Chicago Press, 1995) was the first seriously to analyze the phenomenon of physico-mathematics as a thread in the Scientific Revolution.

[17] Beeckman wrote in December 1619, "there are very few physico-mathematicians" and that "[Descartes] says he has never met anyone other than me who pursues enquiry in the way I do, combining Physics and Mathematics in an exact way; and I for my part, I have never spoken with anyone other than him who does the same." Isaac Beeckman, *Journal tenu par Isaac Beeckman de 1604 à 1634*, 4 vols., ed. C. de Waard (The Hague: Martinus Nijhoff, 1939-53), vol I, 244.

[18] Stephen Gaukroger and John Schuster, "The Hydrostatic Paradox and the Origins of Cartesian Dynamics," *Studies in History and Philosophy of Science* 33 (2002) 535-572, came close to saying this, 538, 545, 547; as did Schuster, "L'Aristotelismo e le sue Alternative", 347. The conception has thus far been made clear in the following conference papers: J.A. Schuster, "*Descartes agonistes—The 'Real' Descartes Stands Up: How the agendas, identities, rebellions, successes, failures and delusions of 'youth' (1618-33) generated the historians' mature Descartes*", Invited Lecture for "Nacht van Descartes", Descartes Centre for the History of the Sciences and the Humanities, University of Utrecht, and Studium Generale, University of Utrecht, October 2008; John Schuster, *"What was Seventeenth-Century Physico-Mathematics?"* for the session on "Connecting Disciplines: Mathematics, Natural Philosophy and Reason in the Early Modern Era," Sixth Joint US/UK/Canadian History of Science Societies Quadrennial Conference, Oxford University, July 2008; J.A. Schus-

ter, *"From Natural Philosophy to Science(s): Transformations (Intended and Unintended), Not Ruptures, in Early Modern Knowledge Network—the Disputed Case of the Early Royal Society,"* First International Conference of ARC Network of Early European Researchers (NEER), University of Western Australia, July 2007; and J.A. Schuster, *"What was the Relation of Baroque Culture to the Trajectory of Early Modern Natural Philosophy,"* Second International Workshop of the Baroque Science Project, Unit for History and Philosophy of Science, University of Sydney, February 2008, www.usyd.edu.au/baroquescience/February_Conference_2008/February_2008_papers/Schuster_Baroque_Nat_Phil_ver_5_1, see pages 22, 23, 24, and 27. The conception of physicalization of the mixed mathematical sciences will be discussed in John Schuster, "Consuming and Appropriating Practical Mathematics and the Mixed Mathematical Fields, or Being 'Influenced' by Them: The Case of the Young Descartes," Chapter 2 in *Mathematical Practitioners and the Transformation of Natural Knowledge in Early Modern Europe,* ed. Lesley Cormack (Chicago University Press, in press); and forms a central theme in my monograph in progress *Descartes* Agonistes*: Physico–mathematics, Method and Mechanism 1618-33***.**

[19] Stephen Gaukroger, "The Foundational Role of Hydrostatics and Statics in Descartes' Natural Philosophy," in *Descartes' Natural Philosophy,* ed. Stephen Gaukroger, John Schuster and John Sutton (London: Routledge, 2000), 60-80; Helen Hattab, "From Mechanics to Mechanism: The *Quaestiones Mechanicae* and Descartes' Physics," in *The Science of Nature in the Seventeenth Century: Changing Patterns of Early Modern Natural Philosophy*, ed. Peter Anstey and John A. Schuster (Dordrecht: Springer, 2005), 99-129.

[20] For example, to see Harriot working out his own mechanics of corpuscles on analogy to the behaviour of light, see Russell Smith, "Optical Reflection and Mechanical Rebound: The Shift from Analogy to Axiomatization in the Seventeenth Century, Part 1," *British Journal for the History of Science* 41 (2007), 1-18.

[21] Gaukroger, *Descartes: an Intellectual Biography*, chapter 3; Gaukroger and Schuster, "The Hydrostatic Paradox," 550-558.

[22] On the physico-mathematical hydrostatics, Gaukroger and Schuster, "The Hydrostatic Paradox"; on the optics, John Schuster, "Descartes *Opticien:* The Construction of the Law of Refraction and the Manufacture of its Physical and Methodological Rationales 1618-1629" in *Descartes' Natural Philosophy,* ed. S. Gaukroger, J.A.Schuster and J. Sutton (London: Routledge, London, 2000), 258-312; the physico-mathematical valencies of the work on falling bodies are treated in chapter 3 of my forthcoming monograph, *Descartes* Agonistes*: Physico–mathematics, Method and Mechanism 1618-33***.**

[23] Clarke terms Stevin (1548-1620) a contemporary (23) of Descartes (1596-1650), a chronologically and, more important, a historiographically misleading proposition. Stevin was the very exemplar of a multi-faceted sixteenth-century engineer figure, a maestro of practical and mixed mathematics, redolent of what we might call the preparatory or "Renaissance" phase of the Scientific Revolution (Schuster, "The Scientific Revolution"); Descartes was the prototypical systematic natural philosophical combatant of the "critical" phase of the Scientific Revolution. They were linked through Beeckman's (and Descartes') concern with promoting mixed mathematics into the natural philosophical realm and with the emerging rhetoric of utility, progress and conquest of nature. (Beeckman had contact with the elder Snel, Rudolph, father of young Willebrod who independently discovered the law of refraction of light around the time Descartes succeeded, Rudolph Snel having been a student and associate of the great Stevin.) Some deep conceptual lines of filiation run from Stevin to Descartes as Gaukroger and Schuster, "The Hydrostatic Paradox," attempt to show in a limited domain of concern. The question of their actual relations, beyond not being contemporaries, is so interesting and revealing that I can report that I was asked a question about it over thirty-five years ago as part of my "qualifying examinations" (to proceed to write a thesis) in the HPS Program at Princeton. Neither I, nor I believe anybody else, has yet fully answered it.

[24] This point and the material in the next paragraph draw on Schuster, "Descartes *Opticien*". Those interested should consult the alternative discovery account in A.I. Sabra's ground breaking study of optics and theories of light in the seventeenth century, "Theories of Light". The remaining serious possibility is owing to Mark Smith, "Descartes' Theory of Light and Refraction: A Discourse on Method," *Transactions of the American Philosophical Society* 77 pt 3 (1987), 1-92. All these accounts agree in discounting the seventeenth century suspicion that Descartes plagiarized the law from Snel. Thomas Harriot possessed the law before either Snel or Descartes but did not reveal it publically: J. Lohne, "Zur Geschichte des Brechungsgesetzes," *Sudhoffs Archiv* 47 (1963), 152-72; J. Lohne, "Thomas Harriot (1560-1621) The Tycho Brahe of Optics," *Centaurus* 6 (1959), 113-21; Gerd Buchdahl, "Methodological Aspects of Kepler's Theory of Refraction, *Studies in the History and Philosophy of Science* 3 (1972), 265-98 at p.284. My own account suggests that Descartes (and Snel) used a technique virtually identical to that originally pursued by Harriot. Such cases of well prepared (nearly) simultaneous discovery are endemic in the history of science, and a primarily sociological literature has grown up around the phenomenon, stemming from the initial studies of the pioneering sociologist of science, Robert K. Merton.

[25] This conceit of "seeing (natural philosophical) causes inside well grounded mixed mathematical results" emerged in discussion of "Baroque Optics" with my colleagues, Dr. Ofer Gal (Unit for HPS, University of Sydney) and Dr. Sven Dupré (Department of History of Science, University of Ghent). We are putting this notion to work in current research on the physico-mathematization of optics in the work of Kepler and Descartes.

[26] Beeckman's much more "Newton-like" version of the principle of inertia appears in his diary for 1613: "...a stone thrown in a vacuum is perpetually moved; but the air hinders it by striking it anew and thus acts to diminish its motion. Indeed, what the philosophers say, that a force is impressed in the stone seems without reason. For who can conceive what that force would be, or how it would maintain the stone in motion, or in what part of the stone it would find its seat?" Beeckman, *Journal*, vol. I, 24-5.

[27] On Newton's conception of inertia and its genealogical relations to Descartes' notions of force and "determination," see Alan Gabbey, "Force and Inertia in the Seventeenth Century: Descartes and Newton," in *Descartes: Philosophy, Mathematics and Physics*, ed. Stephen Gaukroger (Brighton, Sussex: Harvester, 1980), 230-320. On the metaphysical shaping and grounding of Descartes' concepts in dynamics, see: Martial Gueroult, "The Metaphysics and Physics of Force in Descartes" in *Descartes: Philosophy, Mathematics and Physics*, Gaukroger, ed., 196-229; and Daniel Garber, *Descartes' Metaphysical Physics* (Chicago: University of Chicago Press, 1992), chapters 6,7,8. On what one means by Descartes' dynamics, including his conception of "determination," see Peter McLaughlin, "Force, Determination and Impact," in *Descartes' Natural Philosophy*, 81-112; Gaukroger, *Descartes: An Intellectual Biography*, 229-49; and Gaukroger and Schuster, "The Hydrostatic Paradox," 563-70. It should be noted that Garber is especially instructive on Scholastic usages and issues persisting in the work of Descartes, particularly at the "join," as Garber terms it, between Descartes' metaphysical constructions and his natural philosophy. Garber even supplies powerful Scholastic counter-arguments to Cartesian positions, for example in his chapter 4. Again, we hardly have a desiccated and obsolete Aristotelianism, let alone one from which Descartes has performed a rupture into modernity.

[28] That would seem to be the core concern of an intellectual or scientific biography. Otherwise it would be hard to see how such a work could transcend mere narrative of ordinary life events and contingencies. However, Don Howard has also forcefully pointed out in this journal recently that there is always therefore a danger of over dramatizing the biographical subject as the nodal hero of all the intersecting fields and forces. As he observes, it is an empirical question (and judgment) how important the biographical subject's intersection with, and

intervention in, the wider fields really was: "Time for a Moratorium? Isaacson, Einstein and the Challenge of Scientific Biography", *Journal of Historical Biography* 3 (Spring 2008) 124-133. It is clear that Descartes was a first class player in his fields of activity, and that his work was later widely discussed and renegotiated—hence he is, in a non-Whiggish sense, a significant figure. It is also obvious that if we do not come to grips with the actual fields of play, nothing useful in scientific biography is likely to eventuate. On this issue, approached from the perspective of the attempt to reconstruct the actor's (shifting) structures of concept and relevance, see J.A Schuster, "Descartes Agonistes: New Tales of Cartesian Natural Philosophy," *Perspectives on Science* 3 (1995), 99-145, 111-114.

[29] Material in last three sentences and in next paragraph derives from John A. Schuster, "'Waterworld': Descartes' Vortical Celestial Mechanics and Cosmological Optics—A Gambit in the Natural Philosophical Agon of the Early 17th Century," in *The Science of Nature in the Seventeenth Century: Patterns of Change in Early Modern Natural Philosophy*, ed. P. Anstey and J.A. Schuster (Dordrecht: Springer, 2005), 35-79.

[30] Clarke cites Jean–Paul Weber, *La Constitution du texte des Regulae* (Paris: Société d'Éditions d'Enseignement Supérieur, 1964) at note 62 on page 86. Clarke attributes to Weber the idea that the *Rules* were "originally conceived to have three sets of twelve rules each," a point specifically ruled out by Weber's findings, since the *Rules*, composed and revised in stages, had no such "original" plan" (see below). Moreover, the idea of a complex composition over eight or nine years, actually attributable to Weber, is simply stated as fact on the previous page, with no citation to anybody, as though this huge (and fundamentally correct) hermeneutical conclusion is simply common knowledge.

[31] Clarke picks up this point, (91) failing to cite some of the people who first made it. Cf. John Schuster, "Descartes' *mathesis universalis*: 1618-1628," *Descartes: Philosophy, Mathematics and Physics*, Gaukroger, ed., 41-96, 49-51. Gaukroger, *Descartes: An Intellectual Biography*, 99.

[32] So-called by Weber, of course, who first showed this. After Weber, others further articulated his findings, for example, Schuster, "Descartes' *mathesis universalis*," 51-55, and Gaukroger, *Descartes, An Intellectual Biography*, 111ff, which builds on a synthesis of Weber and Schuster. Weber is not cited in connection with Rule 4B and neither is anybody else.

[33] Schuster, "Descartes' *mathesis universalis*," 54. On the nature of the method and its elaboration out of universal mathematics, John A. Schuster, "Cartesian Method as Mythic Speech" in *The Politics of Rhetoric of Scientific Method:*

Historical Studies, ed. John Schuster and Richard Yeo (Dordrecht: Reidel, 1986), 33-96, especially 40-59.

[34] The best introduction to the general idea of the vacuity of grand method-talk is neither Kuhn, nor the books of Feyerabend, but rather a little-noticed brilliant paper: Paul K. Feyerabend, "Classical Empiricism" in *The Newtonian Heritage*, ed. R. E. Butts and J. W. Davis (London: Blackwell, 1970), 150-170. On the structural dynamics of Descartes' "method-talk" and the intimate interrelation of its seductive rhetorical power and inescapable practical impotence, see Schuster, "Cartesian Method as Mythic Speech"; and John A. Schuster, "Whatever Should We Do with Cartesian Method?— Reclaiming Descartes for the History of Science" in *Essays on the Philosophy and Science of René Descartes,* ed. Stephen Voss (Oxford, Oxford University Press, 1993), 195-223.

[35] This Clarke readily accepts and states (see below Note 40), again not citing any relevant literature that has established these claims in the history and philosophy of science.

[36] Schuster, "Whatever should we do with Cartesian Method?", 201-203; Schuster, "Descartes *Opticien*," 300-302.

[37] Clarke has much of interest to say at various points about Descartes' long relationship with Marin Mersenne; however, nothing in particular is made of Mersenne's likely strong influence on the less experienced Descartes at this juncture in the mid to late 1620s. Not cited is important work on just this period in Mersenne's life by Robert Lenoble, *Mersenne ou la naissance de la mécanisme* (Paris: Vrin 1943); Peter Dear, *Mersenne and the Learning of the Schools* (Ithaca: Cornell University Press, 1988) and Richard Popkin, *The History of Scepticism from Erasmus to Spinoza* (Berkeley: University of California Press, 1979; 1st edition 1964). We do hear a lot about a Parisian cultural and Pyrrhonian (sceptical) crisis of the 1620s but, again, nothing from Popkin, nor from the classical literature, for example, René Pintard, *Le Libertinage érudit dans la première moitié du XVIIe siècle*, 2 vols (Paris: Boivin, 1943). Gassendi, for example, was a player in this situation, along with Mersenne. He is mentioned by Clarke as a critic of the *Meditations*, but his role as a player in the cultural turmoil and as a natural philosophical competitor of Descartes in mechanical philosophy is never mentioned, nor is any literature concerned with the matter.

[38] Schuster, "Descartes' *mathesis universalis*," 58-69; extending and modifying Weber, "Constitution," 88-103.

[39] Schuster, "Descartes' *mathesis universalis*," 73-80. Clarke notes that Descartes began to work on metaphysics in 1630, but there is no indication that this might mark a response to or inflection from the project of the *Rules*, or

that anybody has ever thought so—the linkages of metaphysics and natural philosophy, both emerging just after the *Rules* are abandoned, is never problematised.

[40] For example, on pages 89 to 91 Clarke makes the following claims about the *Rules*, Descartes' method, mathematics and other issues, without any attribution to the literature where they were first enunciated: [1] Descartes may have abandoned the *Rules* because [a] they are too general to provide any specific advice about how to develop theories in optics or physiology; and, [b] they require a degree of certainty that was not feasible in natural science. Claim [a] actually derives from Schuster, "Descartes' *mathesis universalis*," 73-79, where the status of Descartes' optics, physiology (and psychology) in propping up the method inside the text of the *Rules* are reflexively called into question. Claim [b] is owing to Clarke himself, as explained earlier, and was to that end explicitly cited by Schuster "Descartes' *mathesis universalis*" Note 153 to page 75. [2] The other immediate reason for abandoning the *Rules* was Descartes' inability to construct problem-solving techniques that would apply to all problems, including mathematical ones. This claim conflates two possible points which are logically independent of each other: [c] that the method cannot command any particular discipline let alone a set of them and [d] that the *Rules* failed at the point where Descartes' attempt to *legitimate* the procedures of universal mathematics collapsed and the text was left unfinished—Descartes could do the mathematics, but his method-based legitimatory machinery, in the latter portions of the extant *Rules* did not work, he suddenly realized. Now, [c] is a general finding in post-Kuhnian history and philosophy of science (see Note 34 above) which was developed and specifically applied to Descartes' mathematics, optics and natural philosophy in the papers cited there; whilst [d] is a finding unique in Schuster, "Descartes' *mathesis universalis*." [3] Clarke's concise and precise assault on the ambitious—and in fact, impossible—promises of Descartes' method (91) seems difficult to conceive without the literature in Note 34 above having been available for many years, yet they are not cited anywhere in the book. Let us be clear: scepticism about Descartes' method is not an abundant commodity in the Francophone or Anglophone branches of the Descartes industry. Schuster, "Whatever should we do with Cartesian method?", 95-6; "Cartesian Method as Mythic Speech,"38-40. (Not even mitigated sceptics about the claimed reach of Cartesian method, such as Elie Denissoff and E.J. Dijksterhuis, who both in effect limited the method to an efficacy in "mathematical physics," are cited.) Thus, it is gratifying to find that original and somewhat "untimely" claims embedded in the literature for almost a generation, and which indeed have attracted critical comment, and not a few citations, from time to time, have now, via Clarke's work, passed into

the realm of what my friends in the legal profession might term "commonly known matters of fact"—apparently they are universally known, consensually agreed, and have no known source.

41 Quentin Skinner and his school have taught us, along with the leading "post-Kuhnian" historical sociologists of scientific knowledge, such as Stephen Shapin and Barry Barnes, that "influence" means not some mystical intellectual action at a distance, but rather that subsequent players found numerous occasions to adopt, adapt, change and renegotiate claims and findings embedded in Descartes' corpus of work. That one's claims and their worth are entirely in the hands of subsequent rounds of "users" is an axiom as true in the dynamics of the natural sciences as it is in intellectual history generally.

42 Peter Dear, "Revolutionizing the Sciences," John Henry, *The Scientific Revolution and the Origins of Modern Science,* 3rd edition (London: Palgrave, 2007).

See more ideas about Scientific revolution, Revolution and Scientific method.Â Descartes was one of the first to abandon traditional methods of thought based on Aristotleâ€™s teachings. Instead, he promoted a new science based on observation and experiments. For this, he has been called the father of modern philosophy.Â Robert Boyle - natural philosopher, chemist and physicist. He is one of the founders of modern chemistry. He is best known for Boyle's Law which describes the inversely proportional relationship between absolute pressure and volume of a gas. Robert Boyle - chemist, devoted to God, discovered multiple idea's and laws we have now. Robert Boyle 0001 - Ireland - Wikipedia, the free encyclopedia. The Scientific Revolution What Was the Scientific Revolution? â€¢ â€¢ â€¢ A revolution in human understanding and knowledge about the physical universe 17th century Began with Kepler, Galileo Ended with Newton â€œScienceâ€ Before the Scientific Revolution â€¢ Based almost entirely on reasoning â€¢ Experimental method or observation wasnâ€™t used at all â€¢ Science in medieval times â€¢ Alchemy â€¢ Astrology A medieval alchemist Factors Leading to the Scientific Revolution â€¢ Rise of universities â€¢ Contact with non-Western societies â€¢.Â RenÃ© Descartes was one of the most important philosophers and mathematicians of his time; many regard him as the father of modern rationalism. Scholastic natural philosophy closely followed the work of the Greek thinker Aristotle. Indeed, in the Middle Ages, Aristotle was sometimes referred to just as "the philosopher," and medieval thinkers such as Thomas Aquinas developed their own ideas by building on Aristotle's.Â Yet in the 17th century, people like Rene Descartes and Robert Boyle grew dissatisfied with it. And that raises two questions.Â If there was a scientific revolution in the seventeenth century, the tradition that it aimed to turn over and replace, was that of medieval Aristotelian science. In order to better understand the innovations of early modern science, therefore, Han Thomas Adriaenssen in this video outlines some of the key concepts of Aristotelian science, or natural philosophy.