CHAPTER 1: INFLECTION

Introduction: The Bad Ending

The significance of the correspondence between Hooke and Newton was not to be denied, even when their relationships soured again. In the midst of their last and most bitter priority dispute—the one concerning the discovery of the inverse square ratio between gravity and distance—Newton was forced, albeit half-heartedly, to acknowledge at least some debt to Hooke:

> This is true, that his Letters occasioned my findings the method of determining Figures.

He was of course quick to down-play it, adding

> when I had tried [the method] in ye Ellipsis, I threw the calculation by being upon other studies & so it rested for 5 years till upon your [Halley's] request I sought for yt paper, & not finding it did it again & reduced it into ye Propositions shewed you by Mr Paget,

and underscoring:

> but for ye duplicate ratio I can affirm yt I gathered it from Keplers Theorem about 20 years ago. (*Correspondence*, II, 444-5: Newton to Halley, 14 July 1686)

Hooke, of course, found this hard to stomach, and never forgave Newton for taking what he had no doubt was his, namely:

> ... those proprietys of Gravity which I myself first discovered and shewed to this Society many years since, which of late M[r]. Newton has done me the favour to print and Publish as his own inventions. (Hall, "Two Unpublished lectures," 224: *Address* to the Royal Society, 1690)

What stands out very clearly is that the adversaries saw "ye duplicate ratio"—the inverse square ratio between distance and gravity—as the crux of their 1679/80 correspondence, at least in terms of the prestige it was to draw: of all the "proprietys of Gravity," it was the discovery of this ratio for which they were most adamant in their pursuit of credit. To understand why, out of every thing, Newton and Hooke found the numerical constant worth fighting over, we would probably be well advised to consider the situation from Newton's perspective. "The definition of the stake of the struggle is a stake *in* the struggle (even in sciences where the apparent consensus regarding the stakes is very strong)" (Bourdieu, 14); and as in all their disputes, Newton seems to have had much more control over events than Hooke. Newton undoubtedly suspected that even if Hooke did have a case concerning the mathematical issue in question, it was a relatively weak one. First, there was Halley's word that Hooke could *not* prove the inverse square law (*c.f. Correspondence*, II, 441-3: Halley to Newton, 29 June 1686). Secondly, whether he shared Huygens' low estimate of Hooke's mathematical abilities or not, Newton surely felt very secure with his advantage over Hooke where geometrical demonstrations were concerned. It was thus a reasonable step for Newton (to the extent that reason played any part in this struggle) to focus the debate on the 'duplicate ratio' and its proof. The other aspects of the correspondence, concerning which Newton's debt to Hooke was far harder to obscure, could then be neutralized with the dubious acknowledgment "occasioned my findings" (see above), which avoids conceding anymore than is absolutely necessary.

As will be discussed at length in Chapter 3, the inverse square ratio had a long and winding career, in which Newton's proof "from Keplers Theorem" and Hooke's 1680 proclamation were just two stops. And whereas neither Hooke nor Newton deserve credit for being the first who "discovered and shewed" the famous ratio, it was Hooke who first suggested the combination of inertial motion and centripetal force. This he did as early as 1666, when Newton was still pursuing the issue of planetary motions in terms of *centrifugal* force.[1] But I do not intend to succumb to the temptation of belated adjudication of old priority disputes. Determining who indeed "first discovered" the "proprieties" may seem like the historians' core task, and the challenge definitely arouses one's detective instincts, but it also presents a clear trap. The image of a competition entails a definite finishing line, and obscures the work and struggle involved in the very shaping of the sought "findings." In attempting to referee such disputes in hindsight one adopts the framework of the debate, instead of analyzing the establishment of the framework, creating a patina of necessity around the claim for which the credit was sought, as though it is, or was, self evident that this claim was *the issue*. In our case in particular, there was much more to "those proprietys of Gravity which" discussed by Hooke and Newton than the concentration on the inverse square law allows one to notice.

Part A: The Novelty

1. HOOKE'S PROGRAMME

1.1 Early Versions

His correspondence with Newton was not the first time that Hooke had aired his *Programme*; he had done this publicly on two earlier occasions. As a two-page finale to his 1674 Cutlerian Lecture *Attempt to Prove the Motion of the Earth* (henceforth: *Motion of the Earth*, Hooke presented a draft of "a System of the World ... answering in all things to the common Rules of Mechanics:"

> This depends on three Suppositions. First, That all Cœlestial Bodies Whatsoever, have an attraction or gravitating power towards their own Centers, whereby they attract not only their own parts ... but ... also ... all the other Cœlestial Bodies that are within the sphere of their activity; and consequently that not only the Sun and the Moon have an influence upon the body and motion of the Earth, and the Earth upon them, but that [all the planets], by their attractive powers, have a considerable influence upon its motion as in the same manner the corresponding attractive power of the Earth hath a considerable influence upon every one of their motions also. The Second Supposition is this, That all bodies whatsoever that are put into a direct and simple motion, will so continue to move forward in a streight line, till they are by some other effectual powers deflected and bent into a Motion, describing a Circle, Ellipsis, or some other more compound Curve Line. The third supposition is, That these attractive powers are so much the more powerful in operating, by how much the nearer the body wrought upon is to their own Centers. (*Motion of the Earth*, 27-8)

This appendix to the *Motion of the Earth* was Hooke's most elaborate and explicit presentation of his *Programme.* It was also his last public one: as was often the case with Hooke, he never made good on his promise to "hereafter more at large describe" these ideas and the "foregoing observations" leading to them (*ibid.*). But the 1674 presentation was not Hooke's first lecture on his ideas; his earliest and the most basic statement of them was presented in an *Address* to the Royal Society eight years earlier:

> [A]ll the celestial bodies, being regular solid bodies, and moved in a fluid, and yet moved in circular or elliptical lines, and not straight, must have some other cause, besides the first impressed impulse, that must bend their motion into that curve. And for the performance of this effect I cannot imagine any other likely cause besides these two: The first may be from an unequal density of the medium, thro' which the planetary body is to be moved ... But the second cause of inflecting a direct motion into a curve may be from an attractive property of the body placed in the center; whereby it continually endeavours to attract or draw it to itself. (Birch II, 91: May 23, 1666)

The constituents of the "System of the World," which Hooke promised in 1674, were rectilinear attraction between all celestial bodies declining with distance, and inertial motion which that attraction curved. "Inflecting a direct motion into a curve" already comprised the centerpiece of the 1666 Royal Society *Address*. Not so, however, the "attractive property of the body placed in the center." In the earlier version it was still only one of two possible causes that Hooke hypothesized for inflection.

It would have been a real challenge to attempt a 'complete' story of *Hooke's Programme*, following its gradual nurturing by Hooke and ending with the final version laid before Newton. My aspirations are much more modest and fragmented, however, concentrating on Hooke's formation of the two concepts—curving rectilinear celestial motion and all-operating attraction—their final shaping in the correspondence with Newton; and Newton's assimilation of them. This chapter begins by exploring Hooke's development of the notion of curving planetary motion; Chapter 2 follows with a discussion of the concept of "power," and Chapter 3 concludes with Newton's adoption and utilization of these ideas. Credits and priorities aside, a few words first about the significance of the notions presented in *Hooke's Programme*

1.2. What Was at Stake

A good indication for how difficult it was for Hooke's notions to be embraced is the amount of persuasion it took Newton to even consider them. The pressure did not begin with Hooke's letter; Newton was in fact familiar with the 1674 version of *Hooke's Programme*, in spite his repeated avowal to Hooke of being "unhappy as to be unacquainted with your Hypotheses" (*Correspondence* II, 302). His kind remark "I am glad to heare that so considerable a discovery as you made of ye earth's annual paralax is seconded by Mr Flamstead's observations" (301), gives Newton away; the "considerable discovery" he refers to was the parallax observations published as the *Attempt to Prove the Motion of the World*, in the last pages of which Hooke sketches his "System of the World." It hardly matters whether it was a bare-faced lie on the part of Newton, whether he had heard of Hooke's observations only second hand, or whether his little parenthesized qualification of claimed ignorance, *viz*. "(yt I remember)" (300) should be taken seriously. What matters is that whatever he had read or heard about *Hooke's Programme* had failed to make enough impression to stir him to accept the challenge and attempt to solve the riddle of planetary motion according to its prescriptions.

It is therefore hardly a surprise that recruiting Newton required Hooke's obstinate pursuit. His succinctly introduced *Programme* implied and demanded a host of difficult concessions from his reader. The model to which Newton was invited to apply his "excellent method" (*Correspondence*, II, 313) in order to describe the "celestiall motions of the planetts" was of a uniform rectilinear motion which an acceleration-causing power, operating in the manner of gravity from a (non-rotating) center, turns into a trajectory *around* that center. This model portrays the planetary orbit as an *effect*—the outcome of independent, seemingly contingent physical processes. It embeds an uninhibited commitment to treating heavenly bodies just like "all bodies whatsoever," and presents devastating metaphysical and religious ramifications.

We need not however delve into these in order to understand Newton's reluctance. Accepting that "celestial bodies [are] *regular* solid bodies" (my italics) and imagining a "first impressed impulse," by which they are "put into a direct and simple motion," meant abandoning the conception of the orbit as a *given* curve. The notion that "the matter of heaven, in which the planets are situated, unceasingly revolves" because "God, in the beginning ... caused them all to begin to move with equal force ... around certain other centers" (Descartes, *Principia Philosophiæ*, Part III, Articles 30 and 46) was not just a self-evident presumption. It was also one of the most basic tools of the burgeoning celestial mechanics. For example, the evident stability of the God-created orbit implied equilibrium between inward and outward tendencies, which allowed Newton and Huygens to investigate gravity by calculating centrifugal forces.

Hooke's Programme replaced celestial equilibrium with a continuous dynamic-active process of mutual balancing between motion along the tangent and attraction towards the center. In order to adopt this conception, Newton needed to relinquish another self-evident conviction; that continuous attraction towards a center results in the acceleration of the attracted body towards, and final collision with the attracting central body. According to Hooke's model, the attracted planet was expected instead to revolve around the attracting sun. This meant in turn that the stability of the revolution of the planet, *e.g.* the earth, was both unremarkable and possibly less than perfect, especially if "[all the planets], by their attractive powers, have a considerable influence upon its motion as in the same manner the corresponding attractive power of the Earth hath a considerable influence upon every one of their motions also." In other words *Hooke's Programme* implies that the planetary orbits may not be exactly closed; one does not

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